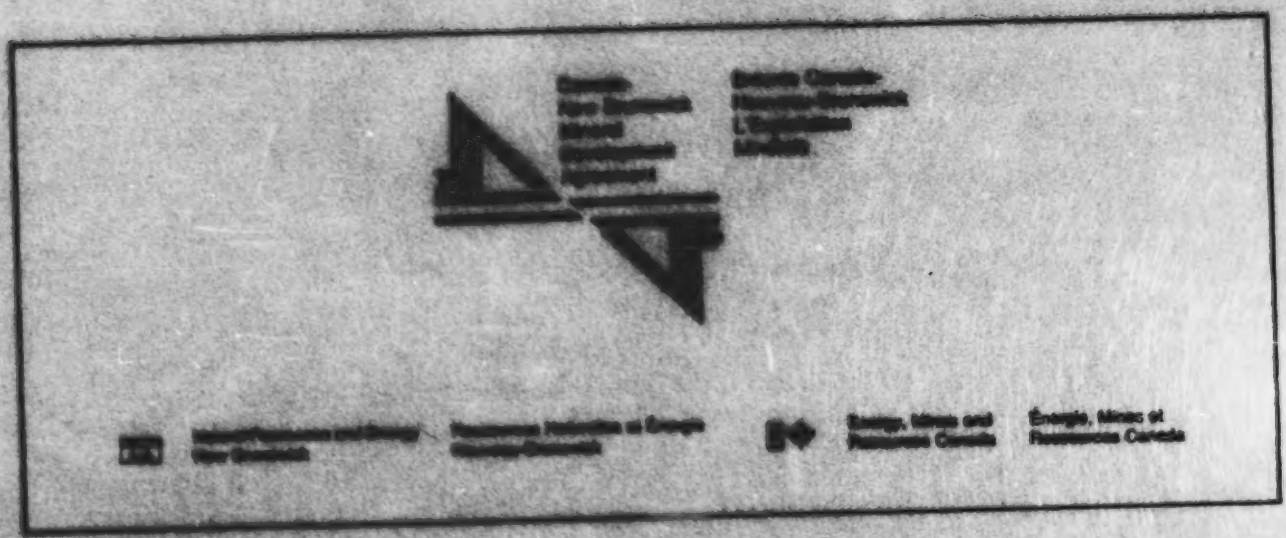
REPORT OF INVESTIGATION 23

GEOLOGY OF NEW DENMARK-SALMON RIVER AREA VICTORIA COUNTY, NEW BRUNSWICK (PARTS OF NTS 21 J/13, 21 J/14, 21 O/3, 21 O/4)

by
R.A. WILSON



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ABSTRACT

The New Denmark-Salmon River area of central Victoria County, New Brunswick, is underlain by rocks of the Aroostook-Matapédia and Tobique zones of the Matapédia Cover Sequence. The Aroostook-Matapédia Zone comprises Upper Ordovician to Lower Silurian rocks of the Grog Brook and Matapédia groups, which feature bedforms typical of deep basinal flysch sedimentation. The Grog Brook Group consists of argillite, sandstone, and minor silty limestone. Two lithofacies of the Matapédia Group can be identified: a predominant carbonate facies (ribbon rock) composed of argillaceous limestone and calcareous argillite, and a local noncalcareous siliciclastic facies (New Denmark Argillite). The Tobique Zone is underlain by Lower Silurian shelf deposits of the Perham Group and by Lower Devonian shallow marine to subaerial volcanic rocks and shallow marine sedimentary rocks of the Tobique Group. Two units have been assigned to the Perham Group: the Hazeldean Formation and the Chambord Brook Limestone. The Hazeldean Formation, comprising the oldest rocks in the Tobique Zone, is a newly defined unit of Lower Silurian calcareous siltstone and sandstone. The Middle to Upper Silurian Chambord Brook Limestone occupies a narrow fault-bounded wedge situated along the Salmon River.

The Lower Devonian Tobique Group has been subdivided into two formations: the Cameron Mountain Formation and Wapske Formation. The Cameron Mountain Formation is a newly defined unit of bimodal volcanic rocks and minor sedimentary rocks that disconformably overlie the Hazeldean Formation. Four conformable members of the Cameron Mountain Formation can be recognized. From oldest to youngest these are: (1) the Polymictic Conglomerate Member, lying disconformably on the Hazeldean Formation; (2) the Lower Felsic Member, consisting of flow-banded rhyolite, felsic pyroclastic rocks, and local mafic volcanic and volcaniclastic rocks; (3) the Mafic Volcanic Member, consisting of massive to pillowed basalt, amygdaloidal and vesicular basalt, and local mafic tuff, hyaloclastites, quartzose sedimentary rocks, and felsic volcanic rocks; and (4) the Upper Felsic Member, which both overlies and interfingers with the Mafic Volcanic Member and consists of mainly massive aphanitic rhyolite. The Wapske Formation conformably overlies the Cameron Mountain Formation and consists of argillaceous to quartzose or arkosic, calcareous to noncalcareous sandstone and siltstone, with minor shale and slate. Post-Lower Devonian mafic stocks, plugs, and dykes intrude Matapédia Group and Tobique Group lithologies. Mississippian terrestrial redbeds of the Plaster Rock Basin are in fault contact with, or lie unconformably upon, the Tobique Group.

Upper Ordovician to Lower Devonian rocks have been affected by a single episode of compressive deformation (Acadian Orogeny), producing a northeast-trending, incipient to well-developed fracture or slaty cleavage that is axial planar to close to tight macroscopic and mesoscopic folds. In the Matapédia Group, vertical folds related to the main deformational episode are developed on the limbs of local, northwest-trending precleavage macroscopic folds. The major faults in the area are the northeast-trending MacKenzie Gulch, Rocky Brook-Millstream, and Blue Bell faults.

RÉSUMÉ

La région de New Denmark-Salmon River, au centre du comté de Victoria au Nouveau-Brunswick, présente des formations rocheuses des zones Aroostook-Matapédia et Tobique de la séquence de couverture Matapédia. La zone Aroostook-Matapédia comprend des roches, datant de la fin de l'Ordovicien au début du Silurien, des groupes Grog Brook et Matapédia, qui sont caractérisés par des couches typiques de la sédimentation de flysch en cuvette profonde. Le Groupe de Grog Brook se compose d'argilite, de grès et de faible quantités de calcaire silteux. Deux lithofaciès du Groupe Matapédia peuvent être identifiés, soit un faciès carbonaté prédominant (roche rubanée) composé de calcaire argileux et d'argilite calcaire ainsi qu'un faciès silici-clastique non-calcaire local (argilite de New Denmark). La zone Tobique, quant à elle, est composée de dépôts de plate-forme continentale du groupe Perham du début du silurien et de roche datant du début du dévonien, allant de la roche provenant de milieux marins peu profonds à de la roche d'origine volcanique subaérienne et, enfin, de roche sedimentaire provenant de milieux marins peu profonds du Groupe Tobique. Deux unités ont été assignées au groupe Perham: la Formation Hazeldean et la formation calcaire de Chambord Brook. La Formation Hazeldean, qui présente les plus anciennes formations rocheuses de la zone Tobique, est une unité nouvellement définie d'aleuronite et de grès calcaire du début du Silurien. La formation calcaire de Chambord Brook, qui date du milieu à la fin du Silurien, occupe une étroite fente en biseau bordée de failles, le long de Salmon River.

Le Groupe Tobique du début du Dévonien a été subdivisé en deux formations : la Formation Cameron Mountain et la Formation Wapske. La Formation Cameron Mountain est une unité nouvellement définie de roches volcaniques bimodales et de faibles quantités de roches sédimentaires qui se superposent, de manière discordante, à la Formation Hazeldean. Il est possible de reconnaître quatre membres concordants de la Formation Cameron Mountain. Du plus âgé au plus récent, on reconnaît 1) un membre de conglomérat polygénique reposant de manière discordante sur

la Formation Hazeldean, 2) un membre felsique inférieur, constitué de rhyolite rubanée, de roches pyroclastiques felsiques, de roches mafiques volcaniques et volcaniclastiques locales, 3) un membre mafique volcanique, constitué de basalte allant de formations massives à des formations en coussinet, de basalte amygdaloidal et labyrinthique, de tuf mafique local, d'hyaloclastites, de roches sédimentaires quartzeuses et de roches volcaniques felsiques et 4) le membre felsique supérieur qui, à la fois repose et interdigite le membre mafique volcanique, est constitué surtout de rhyolite aphanitique. La Formation Wapske repose de façon concordante sur la Formation Cameron Mountain et est constituée de grès et d'aleunorite qui varient du type argileux au type quartzeux ou feldspatique au type calcaire à non calcaire, ainsi que de schistes argileux et d'ardoise en faible quantités. Les stocks, bouchons et dykes mafiques datant d'après le début du Dévonien font intrusion dans les pétrographies des groupes Matapédia et Tobique. Les formations terrestres de roche rouge datant du mississipien de la cuvette de Plaster Rock sont en contact, sous forme de failles, ou reposent de façon discordante sur le Groupe Tobique.

Les roches de la fin de l'Ordovicien et du début du Dévonien ont été affectées par un unique épisode de déformation compressive (orogénie acadienne), qui a produit une fracture ou un clivage ardoisier allant de naissant à bien développé, à tendance nord-est, placé en plan axial par rapport aux plis macroscopiques et mésoscopiques allant de fermés à serrés. Dans le Groupe Matapédia, les plis verticaux reliés à l'épisode de déformation principal se sont développés sur les lèvres de plis macroscopiques pré-clivaux à tendance nord-ouest. Les principales failles de la région sont les failles à tendance nord-est de MacKenzie Gulch, de Rocky Brook-Millstream et de Blue Bell.

GEOLOGY OF NEW DENMARK-SALMON RIVER AREA VICTORIA COUNTY, NEW BRUNSWICK (PARTS OF NTS 21 J/13, 21 J/14, 21 O/3, 21 O/4)

INTRODUCTION

This report describes the geology of the New Denmark-Salmon River area of Victoria County, northwestern New Brunswick (Figure 1). The area is east of the Town of Grand Falls. The purpose of this project was to provide detailed geological data for a portion of the County where the geology has been only superficially mapped, and thus to stimulate mineral exploration. This work was funded by the Canada - New Brunswick Mineral Development Agreement.

Data obtained from this field mapping programme was collected and compiled at a scale of 1:20 000. The NTS numbers, sheet names, and Minerals and Energy Division plate numbers (in parentheses) are:

21 J/13h Cameron Mtn. Range area (Plate 89-267)
21 J/14e North View area (Plate 89-268)
21 O/3c Everett area (Plate 89-269)
21 O/3d East Branch Salmon River area (Plate 89-270)
21 O/3e Cedar Brook area (Plate 89-271)
21 O/3f Right Hand Branch Two Brooks area (Plate 89-272)
21 O/4a Foley Brook area (Plate 89-273)
21 O/4h Ryan Brook area (Plate 89-274)

Information from these maps was used to compile a 1:50 000 scale map (Plate 89-72) that was reduced to a scale of 1:70 000 (Plate 89-72(R)) to accompany this report. (Figure 2).

More than a thousand outcrops were examined over a 1250 km^2 area during two field seasons. From these outcrops the following studies were carried out: 140 thin sections of representative rock samples were examined, 20 large samples of fossiliferous rocks were submitted to the Geological Survey of Canada (GSC) for identification and age determination, 31 samples of volcanic rocks were analysed for major and trace elements; and multi-element analyses of 28 samples, mainly of volcanic rocks, were carried out to aid in mineral potential evaluation.

ACKNOWLEDGEMENTS

The author would like to extend his thanks to R.M. Sullivan for excellent collaboration on the field mapping, to L.R. Fyffe

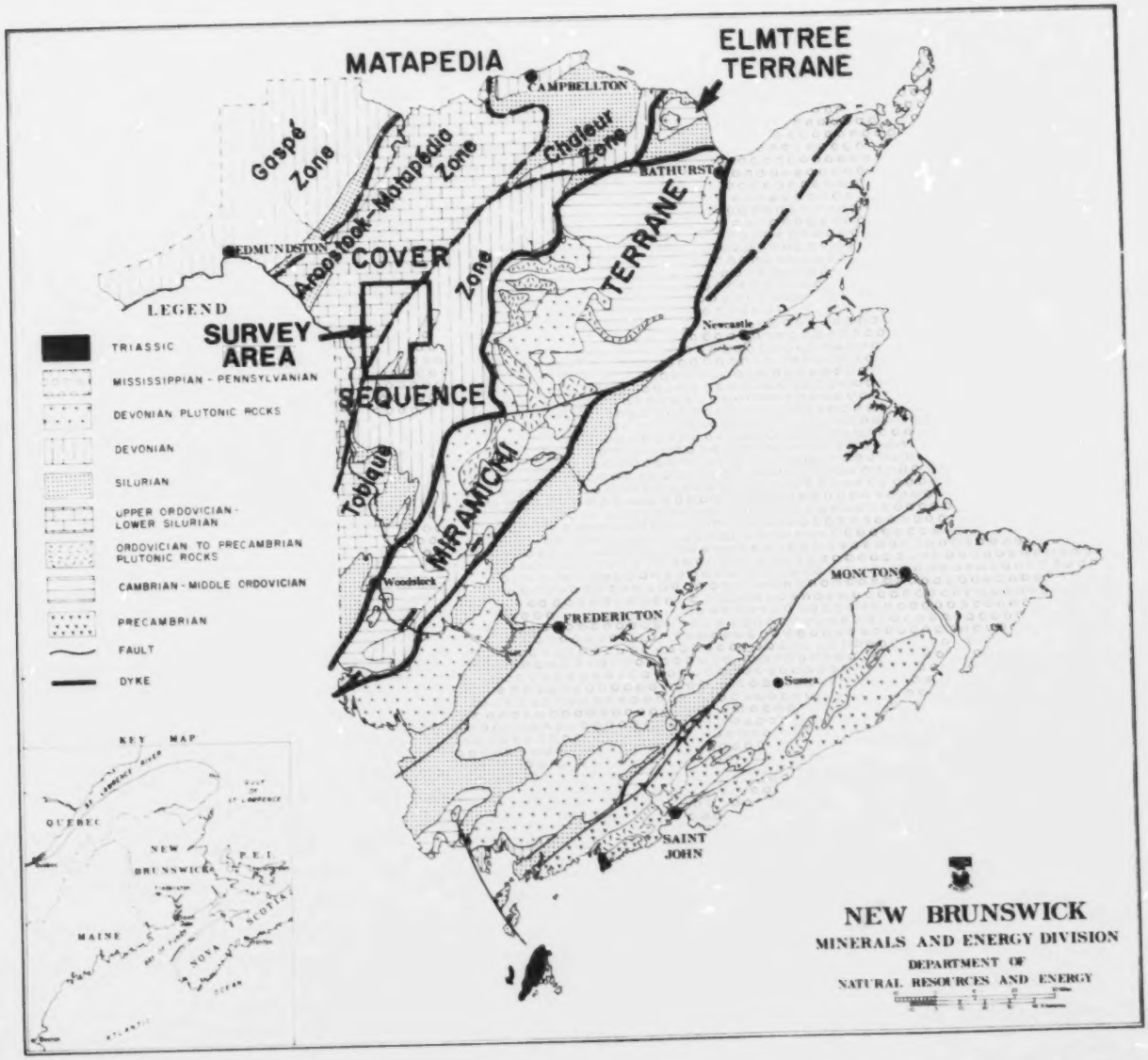

Figure 1. Map showing the New Denmark-Salmon River study area and tectonostratigraphic zones of northwestern New Brunswick.

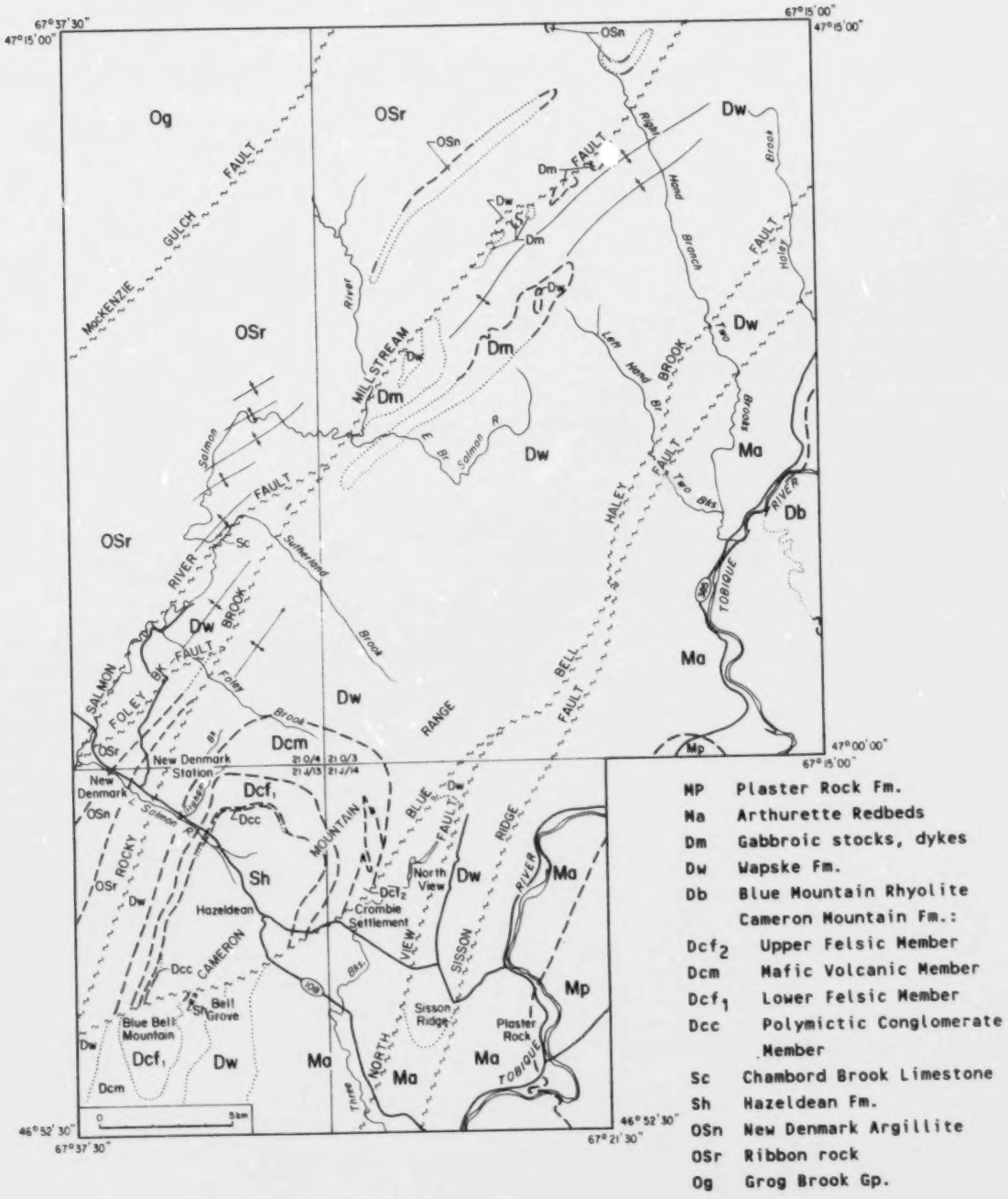

Figure 2. Generalized geology of the New Denmark-Salmon River area (parts of 21 J/13, 21 J/14, 21 O/3, and 21 O/4).

for critical review of the manuscript and for numerous constructive suggestions, to R.R. Irrinki and C. St. Peter for helpful discussions, and to the staff of the Minerals and Energy Division and the Technical Services Branch of the New Brunswick Department of Natural Resources and Energy for logistical support. J. Greenough is thanked for providing the petrography of the mafic dykes. A.J. Boucot provided valuable fossil identifications and paleoenvironmental interpretations. Major- and trace-element geochemistry was carried out by K. Cameron at St. Mary's University, and analyses for metallic elements of economic interest were carried out by X-Ray Assay Laboratories Limited of Toronto. D. Blair typed and B.M.W. Carroll edited the manuscript; T. Leonard and G. Johnson drafted the maps and figures. Information on new road access was furnished through the courtesy of J.D. Irving Limited's Forestry Woodlands Division staff at Veneer and Fraser Inc. staff at Plaster Rock. Special thanks are extended to G. Palser and E. Knowlton of the Renaissance Hotel in Plaster Rock for their hospitality.

PREVIOUS WORK

The first systematic studies of the geology of northwestern New Brunswick were by Rose (1936) in the Carboniferous Plaster Rock Basin, by Nylander (1940) along the upper Saint John River valley, and by Alcock (1941) in the Campbellton-Matapédia area. Anderson (1962) compiled the geology of the Tobique region (NTS 21 O/2, 3, 4, 5, 6, 7), Poole (1964) undertook a regional investigation of north-central New Brunswick (21 O/11, 12, 13, 14), and Potter (1965) mapped in the Upsalquitch Forks area (21 O/10). Hamilton-Smith (1970) carried out a detailed study of Ordovician to Silurian rocks in the Siegas area (21 O/4). Lee and Noble (1977) interpreted the stratigraphy and paleoenvironments of Silurian rocks in the Charlo-Upsalquitch area (21 O/10, 15, 16). St. Peter (1978a) produced the first detailed accounts of the Ordovician to Lower Silurian rocks of northwestern New Brunswick (21 N/8, 9; 21 O/5, 11, 14) and introduced the formal stratigraphic nomenclature for some of these units.

Quarter-mile-scale mapping was carried out by Irrinki (1977a, b, c, d) in parts of NTS 21 O/3 and 21 J/14, and by St. Peter (1978b, 1979, 1981) in parts of NTS 21 J/11, 12, 13, 14. St. Peter (1978b) introduced and formalized the nomenclature of the Lower Devonian rock-stratigraphic units in the Wapske area (21 J/11, 14). Reconnaissance-scale mapping (1:50 000) was undertaken by G.W. Crouse (Fyffe 1982a) on NTS 21 J/13, by R.R. Irrinki (Fyffe 1982b) on NTS 21 J/12, and by Irrinki and Crouse (1986) on NTS 21 O/6. Fyffe (1982c) produced a geological compilation of NTS 21 J/14 based on mapping by various workers. Fyffe and Pronk (1985) described the bedrock

and surficial geology of the Trousers Lake area (portions of 21 J/14, 15, 21 O/2, 3). A detailed account of Upper Silurian to Lower Devonian rocks on the Tobique Indian Reserve near Perth-Andover (21 J/13) was prepared by Pickerill (1986).

Rocks in northeastern Maine, equivalent in age and lithology to those of northwestern New Brunswick, have been described by various authors, including Pavlides (1968), Boucot et al. (1964), Pavlides et al. (1964), Pavlides and Berry (1966), Roy and Mencher (1976), and Roy (1980).

PHYSIOGRAPHY AND GLACIAL GEOLOGY

The survey area is situated in a physiographic region known as the Chaleur Uplands (Bostock 1970). Prior to the Pleistocene glaciations, a long period of erosion created a mature, peneplaned upland with stream patterns similar to their present configuration (Thibault 1980). The survey area can be divided into three distinct physiographic subdivisions that correspond roughly to areas underlain by Carboniferous, Siluro-Devonian, and Ordovician to Silurian strata. A flat lowland has formed in the southern and eastern portions of the map area where Carboniferous redbeds underlying the Tobique River valley and the Anfield area (Plate 89-72(R)) have been susceptible to erosional processes. The Blue Bell Fault defines the northwest limit of this lowland, juxtaposing red Carboniferous sedimentary rocks against folded and more resistant, Lower Devonian sedimentary and local volcanic rocks. This fault forms well-defined scarps west of Three Brooks Deadwater and at the western margin of Haley Plain.

The second physiographic subdivision includes a small area in the extreme eastern portion of the map area around Blue Mountain and a northeast-trending belt through the centre of the map area. It is underlain by Lower Silurian to Lower Devonian volcanic and sedimentary rocks. Strong topographic relief has been produced in areas where felsic volcanic rocks have formed many resistant cone-shaped hills and elongate ridges. In the New Denmark area, northwest of the Blue Bell Fault, topography is dominated by the Cameron Mountain Range, a horseshoe-shaped ridge of Lower Devonian felsic and mafic volcanic rocks. These hills are very steep and streams have deeply incised, V-shaped valleys; relief varies from 150 m on Little Salmon River at New Denmark to 464 m on Blue Bell Mountain and to 572 m on Cameron Mountain. Sisson and Haley brooks have cut steep, V-shaped valleys through Lower Devonian sedimentary rocks near the Blue Bell Fault, where the relief is up to 180 m. Topographic relief becomes more subdued to the north and west so that locally the surface is flat and swampy.

Most outcrops of Lower Devonian rocks are exposed in roadcuts and stream valleys. Despite the rugged topography, outcrops have been obscured by a thick mantle of angular, pebble- to boulder-sized colluvium produced by severe Pleistocene weathering. It appears that pre-Late Wisconsinan periglacial conditions (i.e., extended freeze-thaw cycles) resulted in extensive fracturing and subsequent down-slope movement of colluvium.

The third subdivision, defined as that area northwest of the Rocky Brook-Millstream Fault, is typically very gently rolling to almost flat-lying. It is covered with a thick blanket of glacial till through which the underlying Ordovician to Silurian argillaceous and calcareous sedimentary rocks are only rarely exposed. Some relief is afforded by the larger streams and by local areas of resistant sedimentary rocks.

The glacial history of northwestern New Brunswick and adjacent northeastern Maine has been studied by several workers, including Gauthier (1980), Thibault (1980), Genes et al. (1981), Rampton and Paradis (1981), Rampton et al. (1984), Newman et al. (1985), and Rappol (1986a, 1986b, 1988). As many as four separate ice-movement directions are defined by till fabrics, bedrock striations, and lithotype dispersion patterns (e.g., Rappol 1988). These features, along with the local occurrence of two or more layers of till with glaciofluvial interbeds, record the advance and retreat of regional and local glaciers. These events have not as yet been fully interpreted. Quaternary deposits consist primarily of a blanket or veneer of basal lodgement till and smaller areas of hummocky till, the largest of which is in the Anfield-Bell Grove area (Rampton and Paradis 1981). Glaciofluvial ice-contact deposits are located along Three Brooks, from the Three Brooks Deadwater almost to the Tobique River, and along Dead Brook to about 2.5 km northwest of Blue Bell Lake. The presence of these deposits and the U-shaped valley of Little Salmon River in the Cameron Mountain Range indicate that the direction of ice retreat from the range was to the northwest. The broad U-shaped valleys of the Salmon and Tobique rivers are characterized by ice-contact deposits and by more recent alluvial terrace and flood plain sediments that possibly obscure additional thicknesses of underlying glaciofluvial material.

All streams in the map area drain into the Saint John River via the Tobique and Salmon rivers. These rivers lie in broad, glacially carved, U-shaped valleys that trend northeast-southwest, parallel to large-scale bedrock structures. Most secondary and tertiary streams, typically in V-shaped valleys in Siluro-Devonian physiographic terrain, flow into the major rivers from the northwest or southeast, forming dendritic to rectangular drainage patterns. Some of the drainage systems

appear to have been disrupted by glaciation. Smaller streams in the Carboniferous lowland along the Tobique River and in the gently rolling Ordovician-Silurian terrain northwest of the Rocky Brook-Millstream Fault are typically low gradient, irregularly meandering to dendritic, and often accompanied by swamps and "deadwaters". Some secondary streams featuring U-shaped valleys (e.g., Little Salmon River, East Branch Salmon River, Cedar Brook, Right Hand Branch Two Brooks, and Three Brooks near the Three Brooks Deadwater) were probably glacial channelways.

REGIONAL GEOLOGICAL SETTING

New Brunswick has been divided into a number of pre-Taconian tectonostratigraphic terranes of contrasting lithostratigraphic facies and tectonic styles, and overlying cover sequences (Williams 1983; Fyffe and Fricker 1987). In northern New Brunswick, these include the Cambrian to Middle Ordovician Miramichi Terrane and the post-Middle Ordovician Matapédia Cover Sequence. The Matapédia Cover Sequence, which underlies all of northwestern New Brunswick, has been subdivided into the Gaspé, Aroostook-Matapédia, Tobique, and Chaleur zones (Figure 1), following Rodgers (1970) and Davies (1979). The Matapédia Cover Sequence comprises Upper Ordovician to Lower Silurian slope deposits in the Aroostook-Matapédia Zone and Devonian slope and shelf deposits in the Gaspé Zone (St. Peter 1978a; Stringer and Pickerill 1980). Rocks of the Aroostook-Matapédia Zone grade laterally southeastward into Siluro-Devonian rocks of the Chaleur Zone in northern New Brunswick (Lee and Noble 1977) but are faulted against shallow marine Siluro-Devonian sedimentary and volcanic rocks of the Tobique Zone along the Rocky Brook-Millstream Fault (St. Peter 1978b). The survey area, which is transected by the Rocky Brook-Millstream Fault, straddles the Aroostook-Matapédia and Tobique zones. Regional stratigraphic relationships are summarized in Table 1.

The Aroostook-Matapédia Zone extends from eastern Maine to the Gaspé Peninsula of Quebec. The oldest exposed rocks are tightly folded Caradocian silty argillites and argillaceous sandstones comprising the distal turbidity current deposits of the Grog Brook Group (St. Peter 1978a). The Grog Brook Group is conformably overlain by and interfingers with thinly interbedded Ashgillian-lower Llandoverian calcareous shales and argillaceous limestones of the Matapédia Group (St. Peter 1978a) that have been interpreted as continental slope contourites by Stringer and Pickerill (1980).

The Tobique Zone extends from near Woodstock in western New Brunswick to the Upsalquitch Forks area in north-central New Brunswick. It is juxtaposed against the Chaleur and Aroostook-

TABLE 1. TABLE OF FORMATIONS

SYSTEM/SERIES	GROUP	FORMATION	MAP UNIT	LITHOLOGY
MISSISSIPPIAN		Plaster Rock Fm.	Mp	Red and green shale; limestone; gypsum
		Arthurette Redbeds	Ma	Red sandstone, conglomerate, mudstone
DEVONIAN			Dm	Gabbroic stocks; gabbroic to diabasic dykes
LOWER DEVONIAN	T O B I Q U E	Wapske Formation	Dw	Grey to green quartzose or argillaceous siltstone and fine- to medium-grained, calcareous to noncalcareous, micaceous, quartzose to arkosic sandstone; minor grey to green shale and slate
		Blue Mountain Rhyolite	Db	Red, red-brown or maroon, typically flow-banded, locally porphyritic rhyolite; minor maroon rhyolite tuff, grey to green rhyolite, pillow basalt, and brown to maroon siltstone
		Cameron Mountain Formation	Dcf_2	Upper Felsic Member: pink to red, massive aphanitic rhyolite; minor flow-banded rhyolite, green pillow basalt, quartzose sedimentary rocks and volcanogenic conglomerate
			Dcm	Mafic Volcanic Member: dark grey, dark green or olive green, massive to pillowed basalt; amygdaloidal or vesicular basalt; minor hyaloclastite, mafic tuff, calcareous quartzose siltstone and felsic volcanic rocks
			Dcf_1	Lower Felsic Member: pink to buff, massive to flow-banded, locally porphyritic rhyolite; felsic pyroclastic rocks; local volcaniclastic and mafic volcanic rocks
			Dcc	Polymictic Conglomerate Member: polymictic conglomerate, red to purple or maroon sandstone and siltstone
MIDDLE-UPPER SILURIAN	PERHAM	Chambord Brook Limestone	Sc	Grey to pink limestone, red-brown silty limestone (faulted against Unit OSr)
LOWER SILURIAN		Hazeldean Formation	Sh	Grey to green, massive to parallel-laminated calcareous siltstone and fine-grained sandstone; massive, fine- to medium-grained quartzose sandstone; minor silty shale, lithic grit and sandstone, and polymictic conglomerate
UPPER ORDOVICIAN TO LOWER SILURIAN	MATAPÉDIA	New Denmark Argillite	OSn	Dark grey to black, massive to parallel-laminated argillite; dark grey to light grey-green greywacke, lithic wacke, grit, conglomerate
		Ribbon Rock	OSr	Dark grey to black calcareous shale or argillite, and light grey to black argillaceous limestone; minor noncalcareous shale
UPPER ORDOVICIAN	GROG BROOK		Og	Dark grey to black calcareous to noncalcareous argillite; grey-green sandstone, minor grey silty limestone

Matapédia zones to the north and west, respectively, along the Rocky Brook-Millstream Fault, and against the Miramichi Terrane to the east along the Woodstock and Portage Lakes-Serpentine River fault systems. In the Plaster Rock area, the Tobique Zone is unconformably overlain by nearly flat-lying terrestrial Carboniferous (Mississippian) rocks of the Plaster Rock Basin. This report is concerned only with the pre-Carboniferous units; the stratigraphy of the Plaster Rock Basin has been described by Rose (1936), Hamilton (1965), Skinner (1971), and St. Peter (1979).

The Tobique Zone is underlain for the most part by the Lower Devonian Tobique Group (St. Peter 1978b) and the Silurian Perham Group (Roy and Mencher 1976; Fyffe 1982d). In the survey area, the oldest rocks exposed in the Tobique Zone are lower Llandoverian sandstones and siltstones southeast of New Denmark (Hazeldean Formation). The Hazeldean Formation is disconformably overlain by a thin unit of polymictic conglomerate and associated finer-grained terrestrial sedimentary rocks, indicating uplift of the Matapédia basin or regression of the Silurian sea prior to the onset of bimodal volcanism. This polymictic conglomerate unit forms the basal member of the Cameron Mountain Formation, which also includes two felsic members and a mafic volcanic member. Sparse fossil assemblages collected from calcareous quartzose sedimentary rocks interbedded with the Mafic Volcanic Member near New Denmark are Early Devonian in age. Sandstones and siltstones of the Lower Devonian Wapske Formation are exposed throughout the central portion of the map area and conformably overlie the Cameron Mountain Formation in the New Denmark area.

Post-Acadian mafic intrusive rocks are exposed in the north-central portion of the map area adjacent to the Rocky Brook-Millstream Fault where they have intruded Tobique Group sedimentary rocks. Gabbroic to diabasic dykes intrude sedimentary rocks of both the Aroostook-Matapédia and Tobique zones, and are particularly common in the vicinity of faults.

Competency differences produced contrasting styles of Acadian deformation in the Aroostook-Matapédia and Tobique zones. Tight, upright folds characterize the Aroostook-Matapédia Zone; locally, vertical folds occur on the limbs of northwest-trending, pre-cleavage folds. Devonian strata of the Tobique Zone are characterized by close to tight major folds with local parasitic, S- or Z-shaped, often asymmetric minor folds. Outcrop distribution in the New Denmark area is controlled by a dome-like, doubly plunging anticlinal structure within which mesoscopic, asymmetric doubly plunging minor folds have affected Lower Silurian sandstones and siltstones. Steep, axial planar, slaty or fracture cleavage is associated with folding in all areas, although it is often quite weak in the more competent strata.

Several northeast-trending faults, including the major MacKenzie Gulch, Rocky Brook-Millstream, and Blue Bell faults, offset the various units.

DESCRIPTION OF STRATIGRAPHIC UNITS

GROG BROOK GROUP (UNIT Og)

The oldest rocks exposed in the survey area belong to the Grog Brook Group (St. Peter 1978a), which occupies the central portion of the Aroostook-Matapédia Zone west of the MacKenzie Gulch Fault (Figure 2). It underlies the northwest corner of the map area where bedrock exposure is poor.

Lithology

The Grog Brook Group consists of thin-bedded and parallel-laminated, dark grey to blue-black, calcareous to noncalcareous argillite; grey-green, locally cross-laminated sandstone; and minor pale grey silty limestone. The rock types and primary sedimentary structures are typical of deep basinal deposition resulting from turbid flows (cf. Bouma 1962). Truncated or base-cut-out Bouma sequences have been observed, e.g., **b**, **d**, **b-c-d**, **c-d**, and **c-d-e** intervals (Figure 3). Current ripple and convolute laminations are readily identified in thin to medium beds of sandstone or calcareous sandstone that contain thin, wispy, discontinuous laminae of dark shale or argillite. Load and flame structures are also commonly developed along sandstone-argillite interfaces.

In thin section, argillites containing 40-50% silt-sized (0.02-0.03 mm) quartz grains are gradational to shales containing up to 85% clay minerals. Local calcareous argillites contain up to 20% calcite in the sections examined. Limestone beds and laminae contain up to 85% rounded to irregularly shaped grains of calcite and up to 35% quartz grains. The average grain size is about 0.025 mm.

Contact Relations, Age, and Regional Correlation

Although calcareous lithotypes are atypical of the Grog Brook Group as a whole, they are more common near the conformable contact with the Matapédia Group (St. Peter 1978a; Irrinki and Crouse 1986). The relationship between the two units may be an interfingering one characterized by lateral facies change as suggested by Nowlan (1983a), rather than being one of direct superposition. North of the survey area, the Matapédia and Grog Brook groups are juxtaposed along the MacKenzie Gulch Fault (St. Peter 1978a; Irrinki and Crouse 1986).

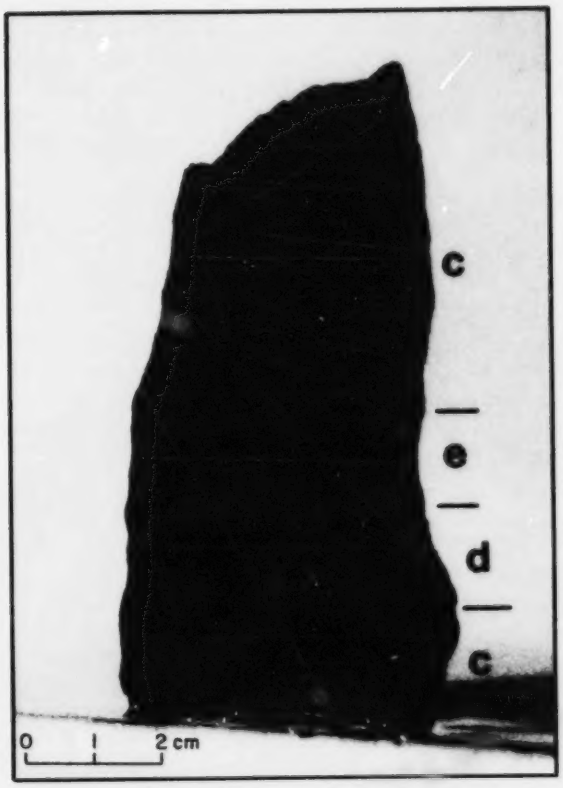

Figure 3. Grog Brook Group lithology illustrating c-d-e base-cut-out Bouma sequence: d interval of parallel laminations is atypical in that thin pelitic layers and some convolute laminations are present. Note lode cast at upper e-c interface. The sample was collected on a logging road near the confluence of Rocky Brook and Little River.

No fossils were obtained from the Grog Brook Group in the survey area; however, graptolites, brachiopods, and bryozoans collected elsewhere indicate a Late Ordovician (Caradocian to Ashgillian) age (Hamilton-Smith 1970; St. Peter 1978a; Malo 1988). Nowlan (1983a), who extracted conodonts of late Ashgillian age from the Grog Brook Group and compared them to similar condonts in the Matapédia Group, demonstrated at least partial time equivalence of the two groups. A diverse trace fossil assemblage has been described by Pickerill (1980).

The Grog Brook Group can be correlated with the Middle-Upper Ordovician Honorat Group (Skidmore 1965) of the Gaspé Peninsula, as they share similar lithologies and occupy a similar stratigraphic position. Malo (1988) suggests, furthermore, that the Grog Brook Group may be, in part, equivalent to the Pabos Formation, i.e., the lower part of the Matapédia Group in the Gaspé Peninsula. In Maine, strata similar to the Grog Brook Group are referred to as the Madawaska Lake Formation of Caradocian to Ashgillian (Late Ordovician) age (Roy and Mencher 1976).

Poor exposure and an unknown degree of tectonic shortening make it impossible to estimate the thickness of the Grog Brook Group in the survey area. However, St. Peter (1978a) has estimated a total thickness of 7600 m, and has suggested a provenance from the northeast, based on paleocurrent indicators.

MATAPÉDIA GROUP

The term "Matapédia Group" was introduced by Alcock (1935) and extended by Skidmore (1965) to describe a sequence of calcareous flysch in the Gaspé Peninsula of Quebec. Its usage was extended to New Brunswick by St. Peter (1978a) to include calcareous rocks flanking the Grog Brook Group in the Aroostook-Matapédia Zone. Deposition occurred in an approximately 20 km wide, southwest-trending trough extending from the Gaspé Peninsula through New Brunswick to the State of Maine.

In the survey area, the Matapédia Group forms a northeast-trending belt that is bounded on the southeast side by the Rocky Brook-Millstream Fault (Figure 2). The continuity of this belt is broken by a small fault block, parallel to Salmon River, that comprises Devonian sedimentary rocks of the Tobique Group. The best exposures of Matapédia Group rocks are along the railway track at New Denmark Station (Figure 4), and along Salmon River from Chambord Brook to Club Brook. In the survey area, two main facies can be identified within the Matapédia Group: a dominant carbonate facies (ribbon rock, Unit OSr), and a less widespread siliciclastic facies (New Denmark Argillite, Unit OSn).

Ribbon Rock (Unit OSr)

The Matapédia Group throughout the Aroostook-Matapédia Zone in Quebec, New Brunswick, and Maine is characterized by a single predominant lithofacies referred to as ribbon rock (Skidmore 1965; Pavlides 1968; St. Peter 1978a; Irrinki and Crouse 1986). The two major lithotypes of this facies are medium-bedded to thinly laminated, dark grey to black, grey-weathering, calcareous to noncalcareous shale and argillite, and pale grey to blue-grey to black, brown-weathering, argillaceous or shaly limestone. However, varying proportions of clay minerals, quartz grains, and carbonates are present; rarely, beds of noncalcareous shale, siltstone, or pure limestone may be found. Contrasting resistance to weathering processes between the two major lithotypes results in its characteristic "ribbon rock" appearance in outcrop (Figure 5). Calcite veins are common in the vicinity of faults, whereas cross-cutting sets of micro-veinlets are locally present.

Beds range in thickness up to 10 cm, although one calcareous argillite bed measured 50 cm. Primary structures typical of turbidity current deposition are less common in the survey area

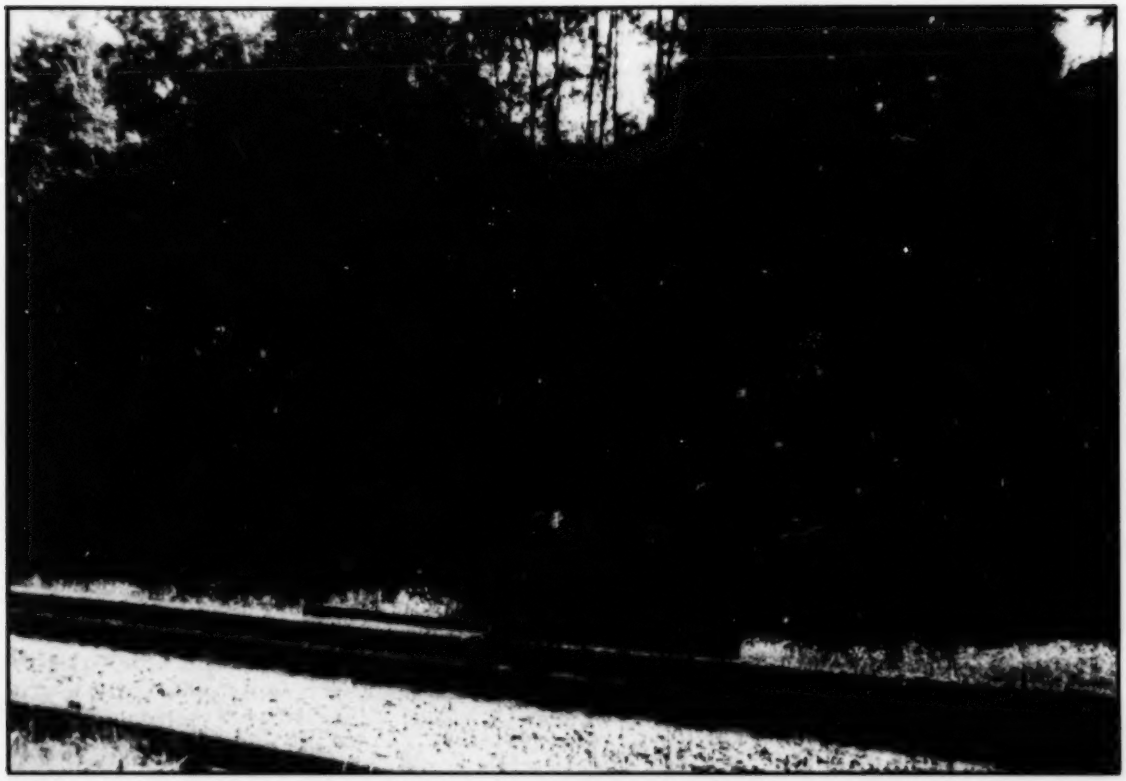

Figure 4. Cleaved calcareous rocks, ribbon rock (Unit OSr) of the Matapédia Group, are exposed along railway tracks near New Denmark Station.

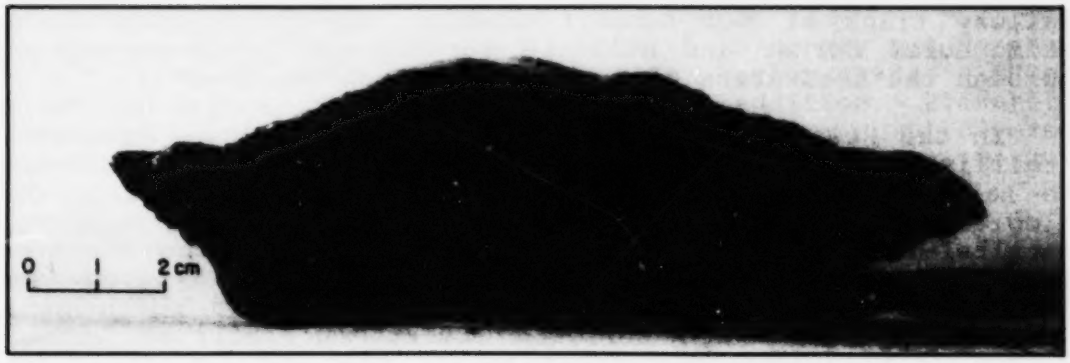

Figure 5. Ribbon rock (Unit OSr) of the Matapédia Group, from the headwaters of Right Hand Branch Two Brooks near the northern boundary of the map area, consists of alternating bands of calcareous argillite and argillaceous limestone.

than in the Grog Brook Group to the northwest. However, parallel laminations typically less than 1 mm in thickness and local convolute or wavy laminations are present. Primary bedforms are similar to intervals **d** and **e** of the classic Bouma sequence; **c** intervals (cf. Bouma 1962) are rare. However, St. Peter (1978a) described complete (**a-b-c-d-e**) sequences and **c-d-e** or **d-e** base-cut-out sequences in the Matapédia Group farther to the north.

Various amounts of clay, carbonate, and quartz grain components have been observed, although the typical range in calcareous argillites is 25-40% quartz, 10-35% calcite, and 40-50% clay minerals, whereas argillaceous limestone beds generally contain 55-80% carbonate, 0-20% clay minerals and 0-40% quartz grains. Muscovite and opaque minerals are usually present in accessory amounts in all lithotypes, with rare biotite or feldspar grains. Grain size does not exceed 0.10 mm in calcareous argillite, and 0.15 mm in argillaceous limestone.

The relative proportions of the two major lithotypes do not vary significantly within the survey area, as far as can be determined from the limited exposure. However, noncalcareous sedimentary rocks are locally dominant within the Matapédia Group, and constitute a minor facies referred to herein as the New Denmark Argillite.

New Denmark Argillite (Unit OSn)

The New Denmark Argillite occurs as narrow horizons of predominantly noncalcareous rocks within the Matapédia Group, and is overlain and underlain by ribbon rock. Irrinki and Crouse (1986) mapped similar rocks to the north of the survey area in the Sisson Branch Reservoir map area, and assigned them to an "Unnamed Unit". The New Denmark Argillite occupies three northeast-trending linear belts in the northern and southwestern portions of the map area. The best exposures are along the railway track at New Denmark Station, on the highway between Salmonhurst Corner and Hilldale Corner, and on a logging road through the headwaters of Right Hand Branch Two Brooks.

In the New Denmark-Salmonhurst Corner area, the New Denmark Argillite underlies an area extending from Foley Brook southwest to Lake Edward, outside of the map area (Fyffe 1982a). Lithologies consist of predominantly dark grey to black, massive to parallel-laminated argillite, slate, or argillaceous siltstone, locally very friable and strongly foliated within apparent shear zones. At one location on the Foley Brook road north of New Denmark, a pale green sericite schist was observed within a narrow shear zone. Shearing is presumably related to movement along one of the major fault systems nearby: the Rocky Brook-Millstream Fault to the east, or the Salmon River Fault to the west. Thin beds of dark grey greywacke, quartzite, and coarse

lithic wacke are commonly observed; within shear zones, these beds are thoroughly disrupted, leaving relict, randomly dispersed, often diamond-shaped boudins up to 25 cm in diameter.

Two northeast-trending horizons of the New Denmark Argillite underlie the north-central portion of the map area, from the East Branch Salmon River to the headwaters of Right Hand Branch Two Brooks. Two main lithologic associations are represented: dark grey to light grey-green, medium-grained lithic sandstone grading to grit and conglomerate (Figure 6), and dark grey to grey-green argillite or argillaceous siltstone containing thin beds or laminations of fine- to medium-grained calcareous to noncalcareous sandstone. Local interbeds of calcareous argillite or argillaceous limestone resemble ribbon rock (Unit OSr). The sandstone, grit, and conglomerate lithotypes are found in much thicker beds in this area than in the New Denmark area, and are typically very hard and massive, resulting in their topographic expression as linear ridges. In thin section, the sandstone is a poorly sorted lithic arenite with an average grain size of 0.1 mm, though some clasts are almost 1 mm in diameter. Clast types include quartz (30%), fresh plagioclase (30%), grains of augite (10%), mafic lithic fragments (10%), chert (5%), calcite (3%), chlorite (2%), sphene (5%), opaques (3%), and accessory epidote and hypersthene. A thin section of conglomerate contained mainly mafic volcanic clasts (75%) plus chert (7%), sedimentary rock clasts (2%), quartz (7%), and plagioclase (8%). Clast size varies from less than 1 mm to 5.5 mm.

Age and Paleoenvironment

Few fossils have been found in rocks of the Matapédia Group. However, graptolites and, rarely, trilobites or brachiopods have been reported from scattered locations in Maine, northwestern New Brunswick, and the Gaspé Peninsula. They indicate a Late Ordovician (mid-Caradocian to Ashgillian) to Early Silurian (mid-Llandoverian) age (Schuchert and Cooper 1930; Pavlides 1968; Lespérance 1968, 1974; Hamilton-Smith 1970; Roy and Mencher 1976; Rickards and Riva 1981; Riva 1981; Nowlan 1981, 1983b; Irrinki and Crouse 1986; Malo 1988). In addition, Pickerill (1980) and Pickerill *et al*. (1987, 1988) have described diverse trace fossil assemblages in the Matapédia Group near Perth-Andover. Near the northern margin of the survey area, grits and coarse sandstones within the New Denmark Argillite contain a number of poorly preserved casts and molds of tabulate corals that are post-Early Ordovician in age.

St. Peter (1978a) has interpreted a relatively deep basinal environment for the Matapédia Group on the basis of observed primary structures and Bouma sequences. The interlaminated and interbedded calcareous argillites and argillaceous limestones comprising the **d** and **e** Bouma intervals in the survey area

Figure 6. Coarse grit (left) and conglomerate (right) of the New Denmark Argillite (Unit OSn) contain abundant mafic volcanic clasts. Samples were collected on a logging road about 1.5 km southeast of Wilson Brook.

appear to conform to the rhythmic interlaminations ("rhythmites") interpreted by Wilson (1969) as representing deposition in basins 100 to 600 m deep. Evidence of deep-water deposition is also provided by the presence of a deep-water Nereites ichnospecies described by Pickerill (1980). Stringer and Pickerill (1980) suggested deposition on a slope by hemipelagic and normal bottom-following contour currents, with periodic introduction of turbidity current deposits, implying a somewhat shallower environment than that proposed by St. Peter (1978a).

Grit and conglomerate beds containing volcanic clasts are present within the New Denmark Argillite in the study area. Similar beds have been observed within the Matapédia Group elsewhere in northern New Brunswick and Maine. Mafic and felsic volcanic clasts were reported in rocks of the "Unnamed Unit" of Irrinki and Crouse (1986) in the Sisson Branch Reservoir area. Greywacke beds of Caradocian to Ashgillian age containing abundant volcanic detritus have been noted in the Carys Mills Formation in Maine (Roy and Mencher 1976), where they are apparently derived from contemporaneous volcanic rocks of the Winterville Formation. In the Popelogan area of northern New Brunswick, Philpott (1988) has mapped grit beds containing clasts

of chert within the basal portion of the Matapédia Group. The chert is derived from the underlying Popelogan Formation, which has been assigned a Caradocian age (Philpott 1988) and which conformably overlies the Goulette Brook Formation, consisting of mafic tuff and hyaloclastite.

The close spatial and temporal association of volcanic rocks with the Matapédia Group at these locations indicates widespread ocean-island volcanic activity within the Matapédia Basin during the Late Ordovician. The assemblage of immature mineral species (particularly augite) in sedimentary rocks of the New Denmark Argillite implies that these rocks were deposited very close to a volcanic centre, and may constitute an epiclastic facies of an eroded (or unexposed) volcanic suite. Irrinki and Crouse (1986) describe turbidity-current-related primary structures and bedforms within their "Unnamed Unit", suggesting that these rocks may represent a channel-fill sequence deposited on a hemipelagic slope. Rapid transport and burial of sediments in such an environment may explain the preservation of unstable mineral assemblages derived from contemporaneous ocean-island volcanic centres.

Regional Correlation and Contact Relations

Ayrton et al. (1969) have presented a detailed account of the regional stratigraphy of rocks similar in age and lithology to the Matapédia Group. In Maine, rocks correlated with the Matapédia Group have been assigned to the Carys Mills Formation of the Meduxnekeag Group (Pavlides 1965, 1966, 1968), formerly the ribbon-rock member of the Meduxnekeag Formation. Farther to the southwest, the Carys Mills Formation merges with clastic rocks of the Central Maine Synclinorium (Boone and Boudette 1989). In the Gaspé Peninsula of Quebec, numerous workers (e.g., Schuchert and Cooper 1930; Crickmay 1932; Alcock 1935; Kindle 1936; Skidmore 1965) have studied the stratigraphy of the Matapédia Group and proposed various nomenclatures. However, in recent years, Lespérance et al. (1987) and Malo (1988) have clarified the stratigraphic relationships and formally subdivided the Matapédia Group into the Pabos Formation and the conformably overlying White Head Formation. No similar subdivision of the Matapédia Group in New Brunswick has yet been attempted, although some correlations with the Gaspé section are possible. The New Denmark Argillite, for example, may correlate with noncalcareous strata containing local sandstone and conglomerate within the Pabos Formation, or with mudstone of the Côte de la Surprise Member of the White Head Formation. The Côte de la Surprise Member has also been correlated (Malo 1988) with the middle slate member of the Carys Mills Formation in the Siegas area in northwestern New Brunswick (Hamilton-Smith 1970) and with calcareous shale and sandstone interbedded with the Matapédia Group elsewhere in northern New Brunswick (St. Peter 1978a).

The undisturbed contact of the Matapédia Group with underlying units, such as the Grog Brook Group in New Brunswick and the Madawaska Lake Formation in Maine, is gradational, interfingering, and diachronous so that the Grog Brook and Matapédia groups are, at least in part, facies equivalents (Nowlan 1983a). Though unexposed in the survey area, the contact is interpreted to coincide with the MacKenzie Gulch Fault, as it does in the Sisson Branch Reservoir map area (Irrinki and Crouse 1986) and Kedgwick map area (St. Peter 1978a). The Matapédia Group is conformably overlain by various local units, e.g., the Upsalquitch Formation in northern New Brunswick (St. Peter 1978a), the Perham Group in northwestern New Brunswick and northern Maine (Ayrton et al. 1969; St. Peter 1978a), the Smyrna Mills Formation in western New Brunswick and adjacent Maine (Pavlides 1968; St. Peter 1982), and the Chaleurs Group in northeastern New Brunswick (Lee and Noble 1977; Noble and Howells 1979). In the survey area, all contacts with younger units are faulted and the original relationships are not observed.

The thickness of the Matapédia Group in the survey area is unknown because exposure is too sparse to evaluate the amount of shortening due to folding. Outside the study area, the unit has a minimum thickness of 200 m (St. Peter 1982) and a maximum thickness estimated to be at least 2800 m in the Grand River area of northwestern New Brunswick (St Peter 1978a).

PERHAM GROUP

Silurian rocks in northwestern New Brunswick and northern Maine have previously been assigned to the Perham Formation (Boucot et al. 1964; Hamilton-Smith 1970; St. Peter 1978a). Perham Formation stratigraphy in Maine was reinterpreted and the unit elevated to group status by Roy and Mencher (1976). Fyffe (1982d) extended this usage to western New Brunswick, where he assigned rocks formerly included in the Smyrna Mills Formation to the newly defined Perham Group. This convention will be followed in the survey area, where two units of Silurian rocks have been included in the Perham Group. The Hazeldean Formation (new name) of Llandoverian age underlies a 30 km^2 area southeast of New Denmark, whereas the informally named Chambord Brook Limestone, of middle to Late Silurian age, occupies a narrow fault-bounded area adjacent to the Salmon River Fault (Figure 2).

Hazeldean Formation (Unit Sh):

The Hazeldean Formation (new name) underlies an elliptical area in the southwestern portion of the map area, southeast of New Denmark. It occupies the core of a large anticlinal structure and is terminated to the south by the Blue Bell Fault. An

outcrop of this unit south of the fault may represent a small inlier or large xenolith within younger mafic volcanic host rocks. The Hazeldean Formation is best exposed along the Canadian National Railway tracks northwest of the level crossing at Hazeldean, at a railway tunnel on an abandoned rail line northwest of Blue Bell Lake, and in road cuts on Route 108 near Hazeldean.

Lithology: The dominant lithotype within this unit is a dark grey to green-grey, typically calcareous and fossiliferous, massive to parallel-laminated siltstone or very fine grained sandstone (Figure 7). These strata contain thin beds or laminations of brown-weathering, calcareous, fine-grained sandstone, and local thin beds of silty shale. Disruptions in bedding planes caused by bioturbation are evident where brown-weathered sandy layers are present, and is also seen in thin sections of some massive siltstone beds. Fossils (mostly brachiopods) are common in most outcrops (Figures 8 and 9), but are absent from local beds of massive, fine- to medium-grained quartzose sandstone.

Feldspar content ranges up to about 20% and calcite (mostly as authigenic cement, with lesser amounts derived from alteration of plagioclase) up to 50% although 10-30% is the norm. Muscovite is generally present in minor amounts and biotite flakes are rare. Detrital quartz grains comprise 30-50% of all lithotypes except shale.

Lithic fragments are generally absent except for two stratigraphic horizons near Hazeldean and Jones Brook where lithic fragments constitute up to 20% of samples. The belt of grey, medium-grained lithic sandstone near Jones Brook lies along strike with, and may be equivalent to, a narrow horizon of polymictic conglomerate (Figure 10). Lithic fragments in these beds are mainly pelitic sedimentary clasts with less abundant felsic and mafic volcanic clasts. Near Hazeldean, lithic fragments in fine-grained dark grey sandstone are almost all sericitically altered felsic volcanic clasts. Alkali feldspars are common where lithic fragments are abundant and, in some samples, grains of fresh microcline were identified.

The matrix constitutes from 5% to 20% of the unit indicating, according to the classification of Blackburn et al. (1978), that both wackes and arenites are present. Clay matrix may constitute up to 60% of the shalier beds, however. In terms of relative abundance, arenites dominate over wackes by a 6:4 ratio. Arenaceous sandstones are typically very well sorted and contain subrounded to subangular, equidimensional to slightly elongate grains with a mean diameter of 0.1 mm, locally up to 0.3 mm.

Figure 7. Parallel-laminated to thinly bedded argillaceous siltstone (dark) and fine-grained calcareous sandstone (light) in the Lower Silurian Hazeldean Formation (Unit Sh), on the headwaters of Merritt Brook, midway between Cameron and Geneau mountains.

Figure 8. Leptaena "rhomboidalis" (left) and Atrypa "reticularis" (right) in calcareous siltstone of the Hazeldean Formation (Unit Sh); samples were collected 1 km east of Burnt Hill Mountain and 600 m southeast of Hazeldean, respectively.

Figure 9. Sample from a fossil bed (Hazeldean Formation) located 600 m north-northeast of Bell Grove.

Figure 10. Polymictic conglomerate from the Hazeldean Formation (Unit Sh), collected on a tributary of Jones Brook, about 1.6 km west of Blue Bell Lake.

Small-scale sedimentary structures include disrupted beds caused by: (1) dewatering of thin argillaceous strata, defined by microshears at bedding interfaces where argillaceous sediment has intruded or has been squeezed into overlying silty or sandy strata; and (2) bioturbation, as noted previously, involving mixing of adjacent strata by benthic fauna; in places, round to ovoid worm burrows are filled with detritus from over-lying beds. Subtle parallel laminations and rare small-scale cross laminations are usually identified by thin (one grain thickness) linear concentrations of opaque material (organic matter?). Bedding planes in massive equigranular sediments could usually be inferred from the alignment of detrital muscovite flakes. Larger-scale sedimentary structures, such as load casts, groove casts, and cross laminations, were observed in only one large outcrop along the CNR track near Route 108, and indicate that the beds are oriented right-way-up.

Age and Paleoenvironment: The fossil collection sites and their Geological Survey of Canada identification numbers are shown on Plate 89-72(R). Fossils previously collected by G. Crouse were identified by A.J. Boucot (written communication, 1982). A Llandoverian (pre-C_6) age was established. The fauna identified in each of these samples are as follows: GSC 98610 - pterineoid, gastropod, trilobite, orthoceroid, Leptaena "rhomboidalis", Stricklandia lens, dolerorthid; GSC 98608 - plectodontid, rhynchonellid, Stricklandia lens; GSC 98612 - plectodontid, tetracoral, bivalve; GSC 98616 - Mendacella sp., leptostrophid, encrinurid, Ptilodictya, gastropod, cranid, rhynchonellid, dolerorthid, Stricklandia lens.

Seven additional samples were collected during this mapping project, and were examined by A.J. Boucot (written communication, 1987, 1988) and by P.J. Lespérance for trilobites (written communication, 1987). In four samples, Boucot noted the presence of Paucicrura, which he has elsewhere assigned to the Caradocian-Ashgillian and which is unknown above the Ordovician. However, the remainder of the assemblage, especially the presence of Meifodia, indicates an early Llandoverian age. The samples containing Paucicrura were collected from the axial zone of the anticlinal structure within which the Hazeldean Formation is exposed, where the oldest strata may be expected to be found. Thus, the oldest exposed portions of this unit record deposition during the latest Ordovician or earliest Silurian. The assemblages identified in each sample are as follow: GSC 101916 - Lophospira sp., Leptaena "rhomboidalis", Skenidioides sp., bryozoans, bivalve, Meifodia sp., trilobites, Paucicrura, unidentified brachiopods (rostrospiroid, strophomenoids); GSC 101918 - Meifodia sp., Zygospiraella (?) sp., Dicoelosia, isorthid, orthid; GSC 101920 - Paucicrura sp., bryozoan, trilobite; GSC 101921 - Leptaena "rhomboidalis", Paucicrura sp., strophomenoid;

GSC 101923 - Platystrophia sp., Meifodia sp., orthotetacid; GSC 101924 - Leangella sp., stropheodontid, bivalve, rhynchonellid, Phacops sp. (trilobite), and a high-spired gastropod; GSC 101925 - Paucicrura sp., Leptaena "rhomboidalis", Sinuites(?) sp., cyclonemid(?) gastropod, Diacalymene sp. (trilobite).

The sedimentary structures and benthic fossil communities observed in the unit are consistent with deposition in a neritic shelf environment. The presence of Skenidioides in GSC 101916 suggests that this environment correlates with Benthic Assemblage 5 of Boucot (1975). Mineralogical and physical variations in the stratigraphic record reflect variations in the proximity of the sediment to its terrestrial source. The local presence of unstable components such as mafic volcanic fragments, biotite flakes, and alkali feldspars indicate a relatively immature sediment that has undergone fairly rapid erosion, transportation, and deposition. However, most of the rocks constituting this unit contain mineral assemblages representative of more mature sediments.

Contacts and Thickness: No estimate can be made of the total thickness of the Hazeldean Formation because the basal contact is not exposed. From a structural reconstruction based on recorded bedding measurements, the thickness of the exposed portion of the formation has been calculated at about 2000 m. However, the exposed thickness may be much less because the frequency of minor folds, and thus the total shortening of the section, is unknown due to the scarcity of outcrop.

The nature of the upper contact of this unit is not clear. Several poor discontinuous exposures in the ditch along Route 380 north of Blue Bell Mountain record a transition, up-section to the west, from grey-green fossiliferous siltstones through reddish maroon, terrestrial siltstones and polymictic conglomerate (Unit Dcc) of the Lower Devonian Tobique Group (described in next section). Reliable bedding trends in these rocks could not be measured because of the small size and two-dimensional exposure of the outcrops. Mottled reddish coloration and rusty weathered fossils near the upper contact of the Hazeldean Formation suggest that it underwent a period of subaerial oxidation prior to deposition of the overlying polymictic conglomerate. It appears, therefore, that an erosional disconformity separates these units. This interpretation is supported by a broad hiatus in the fossil record, between Llandoverian (Early Silurian) fauna in the Hazeldean Formation and Helderbergian (Early Devonian) fauna in the overlying Tobique Group.

Regional Correlation: The reported age of the Hazeldean Formation indicates that it is contemporaneous with and a probable lateral facies equivalent of the upper portion of the

Matapédia Group. The actual relationships are unknown, however, as these two units are separated by the Rocky Brook-Millstream Fault. The Hazeldean Formation is contemporaneous, in part, with the New Sweden Formation in northern Maine (Roy and Mencher 1976) and with the Smyrna Mills Formation in western New Brunswick (St. Peter 1982). To the northeast of the survey area, the Upsalquitch Formation (St. Peter 1978a) is equivalent in age and lithologically similar to the Hazeldean Formation. The Upsalquitch Formation comprises mainly thick-bedded calcareous siltstone with thin parallel laminations of fine-grained bioturbated sandstone or arenaceous limestone of probable Llandoverian age. It is less fossiliferous than the Hazeldean Formation, although one locality near Kedgwick contains Ptilodictya and Leptaena "rhomboidalis" (St. Peter 1978a), which were also identified within the survey area. The basal portion of the Upsalquitch Formation contains a wacke-siltstone turbidite sequence that cannot be correlated with the Hazeldean Formation since the basal portion of the latter is not exposed.

Chambord Brook Limestone (Unit Sc):

On the east bank of Salmon River, just downstream from its confluence with Chambord Brook, are several outcrops of limestone informally referred to as the Chambord Brook Limestone. This unit is exposed along the Salmon River Fault near the Rocky Brook-Millstream Fault. Because of its limited extent and faulted contacts, mapping has failed to determine the position of this unit within the local stratigraphic succession. None of the units underlying northwestern New Brunswick contain limestones resembling the Chambord Brook Limestone. However, near Perth-Andover a narrow belt of fossiliferous calcareous siltstones belonging to the Perham Group has been tectonically emplaced along the Rocky Brook-Millstream Fault (Pickerill 1986). It is believed that the Chambord Brook Limestone has been similarly emplaced between the younger Wapske Formation to the east and the older Matapédia Group to the west. For this reason, and because of its paleontologically defined age (see below), the Chambord Brook Limestone has also been assigned to the Perham Group.

Lithology: The limestones are hard, reddish brown to pale grey or pink biomicrites according to the classification of Folk (1962). A hand specimen is illustrated in Figure 11. In thin section, the red-brown variety consists of 80% fossil fragments and 20% micritic mud matrix, 40% of which is amorphous hematite (imparting its distinctive colour to the rock). The matrix further consists of 5% tiny (0.1 mm) quartz grains, 50% optically diffuse calcite, and a few flakes of muscovite or sericite. Since the fossil fragments are typically in close contact, the rock may be termed a packstone (Dunham 1962). Fragments are subangular with scalloped or corroded margins and sometimes recrystallized to sparry calcite. Eight-five per cent

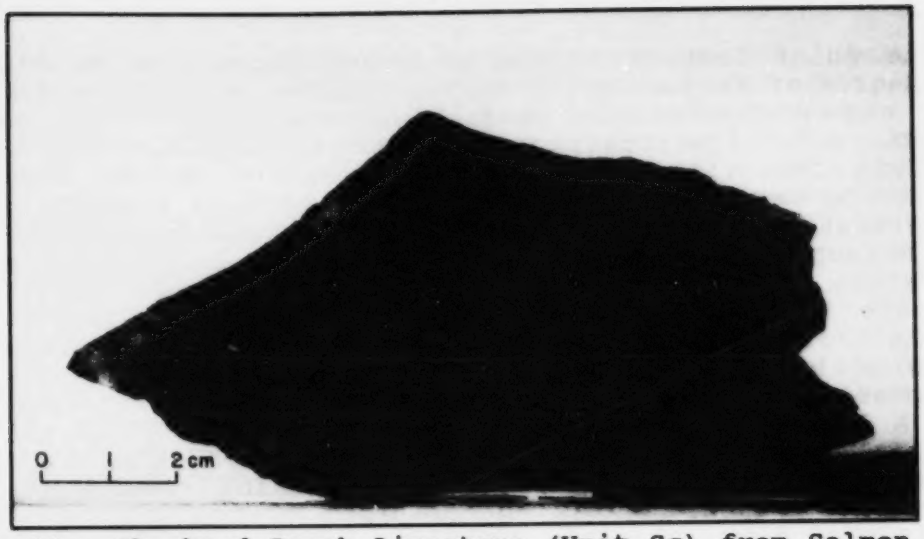

Figure 11. Chambord Brook Limestone (Unit Sc) from Salmon River at Chambord Brook.

of the clasts are coral fragments up to 3 mm in size, 10% are curved shelly fragments (including a few tiny articulated ostracods and brachiopods) up to 2 mm in size, and 5% are crinoid ossicles; trilobites are rare. The grey to pink limestone, containing 60-65% fossil fragments and 35-40% micritic matrix, may be called a wackestone (Dunham 1962). The matrix contains 85% optically diffuse calcite, 5% quartz grains, and clay minerals. Fossil clasts include 75% coral fragments (often recrystallized to sparry calcite so that no relict organic structure remains), 20% shelly fragments including several articulated brachiopods and ostracods, and 5% crinoid ossicles.

Age, Paleoenvironment, and Regional Correlation: Fossil identifications by A.J. Boucot (written communication, 1988) on sample GSC 103061 include Leptaena "rhomboidalis", Atrypa "reticularis"', Leangella(?) sp., Isorthis (Arcualla) sp., Resserella, tetracoral, orthoceroid, trilobite, and unidentified brachiopods. Boucot suggested a Late Silurian age, but pointed out that if Leangella is correctly identified, the rocks may be no younger than Wenlockian (middle Silurian). Thus, it seems likely that the Chambord Brook Limestone represents a slice of the upper part of the Perham Group. Limestones have been recognized in a similar stratigraphic position within the Perham Group elsewhere in Maine and New Brunswick, e.g., in the Jemtland Formation in Maine (Roy and Mencher 1976) and in the upper part of the Smyrna Mills Formation in western New Brunswick (St. Peter 1982).

The chief feature of the Chambord Brook Limestone is the high degree of fragmentation of its fossils, suggesting reworking in a high-energy (i.e., reefal) environment. Richly fossiliferous reefal limestones of mid-Late Silurian age in the Shin Pond and Stacyville areas of northeastern Maine have been reported by Neuman (1967) although they were not formally defined or correlated with well-described Silurian units. However, some of the fauna contained in these limestones are also present in the Salmon River outcrops, suggesting that the paleoenvironment may have been similar. Calcisiltite-biomicrite limestones in the La Vieille Formation (Chaleurs Group) of northern New Brunswick have been described by Lee and Noble (1977). They interpreted these rocks as carbonate bank deposits rather than reefal limestones because of the presence of quiet water, nonreefal tabulate corals and stromatoporoids. However, abundant fossils in the La Vieille Formation have enabled its age to be established as Llandoverian C_6 to early or middle Wenlockian, i.e., considerably older than the Salmon River limestones. Also in northern New Brunswick, stromatoporoidal-stromatolitic reefs are reported by Noble (1985) from the Pridolian LaPlante unit. The LaPlante unit contains tabulate coral bafflestones and biogenic and polymictic breccias that, although apparently younger than the Chambord Brook Limestone, may have shared a similar depositional environment. Elsewhere, fine-grained parallel-laminated sandstones and bioturbated calcareous siltstones in the Perth-Andover area to the south contain a Ludlovian fauna (Pickerill 1986) and may be contemporaneous with the Chambord Brook Limestone.

TOBIQUE GROUP

Lower Devonian sedimentary and volcanic rocks of the Tobique Zone were formally defined as the Tobique Group and divided into the basal Costigan Mountain Formation and conformably overlying Wapske Formation by St. Peter (1978b). The distinction between these formations was based on observations in the Wapskehegan River watershed, about 20 to 40 km southeast of the survey area. There, the Costigan Mountain Formation consists of predominantly subaerial felsic volcanic rocks and the Wapske Formation consists of interbedded felsic to mafic volcanic and sedimentary rocks. However, subsequent mapping has revealed that this subdivision of the Tobique Group needs modification in other parts of the Tobique Zone due to complex interfingering relationships of volcanic rock units.

The Tobique Group is a northeast-trending belt of rocks that underlies about half of the survey area. The Tobique Group has been divided into two major lithostratigraphic subdivisions (Figure 2). The Cameron Mountain Formation (new name) consists

of a mainly bimodal volcanic sequence (Units Dcf_1, Dcm, Dcf_2) south and east of New Denmark, a basal unit of polymictic conglomerate (Unit Dcc), and local interbedded volcaniclastic and quartzose sedimentary rocks. The stratigraphic position of the Cameron Mountain Formation beneath the Wapske Formation (Unit Dw) and the Helderbergian age assigned to fossils contained in beds of sedimentary rock imply that deposition of the Cameron Mountain Formation was contemporaneous with Costigan Mountain Formation volcanism farther to the east.

A narrow belt of felsic volcanic rocks along the eastern boundary of the map area will be referred to informally as the Blue Mountain Rhyolite (Unit Db). The age of the Blue Mountain Rhyolite relative to volcanic rocks of the Cameron Mountain Formation is somewhat problematic, especially since they lie on opposite sides of the major Blue Bell Fault. However, a large outcrop of Wapske Formation sedimentary rocks on a logging road beside Left Hand Branch Two Brooks contains a 3 m section of greyish waterlaid tuff (Figure 12). The tuff, which overlies and is thus younger than the Cameron Mountain Formation, probably represents a distal facies of volcanic activity centred farther east, i.e., within the Blue Mountain Rhyolite.

The Tobique Group is equivalent in age and similar in lithology to the Dalhousie Group (Greiner 1967), which underlies the Chaleur Zone north of the Rocky Brook-Millstream Fault. The Tobique Group has also been correlated with the Dockendorff Group of northeastern Maine (St. Peter 1978b). The Edmunds Hill Andesite, Chapman Sandstone, and Swanback Formation of the Dockendorff Group are equivalent in age (Helderbergian) and lithologically similar to rocks comprising the Tobique Group (Boucot et al. 1964).

Cameron Mountain Formation

The Cameron Mountain Formation (new name) forms the lower part of the Tobique Group section within the survey area, and includes those rocks lying stratigraphically between the Lower Silurian Hazeldean Formation and sedimentary rocks of the Lower Devonian Wapske Formation. The Cameron Mountain Formation has been subdivided into four conformable members: the lowermost member is a relatively thin horizon of terrestrial to shallow marine sandstone, siltstone, and polymictic conglomerate (Polymictic Conglomerate Member, Unit Dcc), which lies disconformably on the Hazeldean Formation. A bimodal suite of volcanic rocks overlies the Polymictic Conglomerate Member and is conformably overlain by sedimentary rocks of the Wapske Formation. Felsic volcanic rocks occupy two stratigraphic horizons: the Lower Felsic Member (Unit Dcf_1) overlies the Polymictic Conglomerate Member and underlies a thick unit of mafic volcanic rocks (Mafic Volcanic Member, Unit Dcm), whereas the Upper Felsic

Figure 12. On Left Hand Branch Two Brooks, a bed of grey tuff (above) is hosted by sedimentary rocks of the Wapske Formation (Unit Dw).

Member (Unit Dcf_2) both overlies and interfingers with the Mafic Volcanic Member. The Cameron Mountain Formation takes its name from the highest peak in the area, which is underlain by resistant volcanic rocks of the Lower Felsic Member.

North of the Blue Bell Fault, Cameron Mountain Formation strata are exposed within a horseshoe-shaped belt on the flanks and nose of a northeast-trending, northerly plunging anticlinal structure. Exposure is poor south of the Blue Bell Fault, but clearly the extension of the Lower Felsic Member is overlain on each side by the Mafic Volcanic Member.

Whole-rock analyses show that felsic and mafic volcanic rocks of the Cameron Mountain Formation form a bimodal suite. The two felsic members (Units Dcf_1 and Dcf_2) consist of rhyolite with SiO_2 content ranging from 69% to 78% (Table 2), whereas the Mafic Volcanic Member consists of tholeiitic basalts containing 43% to 50% SiO_2 (Table 3). The locations of samples that were analysed are shown on Plate 89-72(R). Dostal et al. (1989) concluded from a study of the major-, trace-, and rare-earth-element geochemistry of volcanic rocks in the New Denmark area (i.e., the Cameron Mountain Formation) and elsewhere in the Tobique and Chaleur zones that all were emplaced in an intra-continental rifting environment.

Polymictic Conglomerate Member (Unit Dcc): These rocks, sporadically exposed in the southwestern portion of the map area, overlie the Hazeldean Formation and underlie the Lower Felsic

TABLE 2
MAJOR- AND TRACE-ELEMENT ANALYSES OF FELSIC VOLCANIC ROCKS
OF THE CAMERON MOUNTAIN FORMATION

	46B	56	63A	96	105A	182	185	79	261A
SiO_2	76.95	69.53	76.78	75.04	75.52	78.68	75.68	77.31	73.39
TiO_2	0.19	0.50	0.19	0.24	0.27	0.08	0.17	0.08	0.50
Al_2O_3	11.89	14.93	13.83	13.32	13.20	11.07	13.13	12.75	13.99
Fe_2O_3	1.95	3.48	1.40	1.56	1.02	1.34	1.48	1.04	2.79
MnO	0.04	0.03	0.02	0.03	0.01	0.01	0.01	0.02	0.04
MgO	0.68	0.64	0.77	0.76	0.68	0.62	0.87	0.70	0.57
CaO	0.00	0.62	0.02	0.01	0.00	0.00	0.00	0.07	0.07
Na_2O	2.18	4.93	2.99	2.36	2.88	1.13	2.00	3.56	7.35
K_2O	5.64	4.43	2.31	5.99	5.32	7.28	5.87	3.65	0.35
P_2O_5	0.02	0.09	0.03	0.04	0.04	0.02	0.03	0.02	0.08
L.O.I.	0.8	1.0	2.1	1.1	0.7	0.6	1.2	0.7	0.6
Ba	157	364	133	255	411	69	134	383	55
Rb	195	136	71	159	144	196	188	136	9
Sr	30	138	45	29	36	20	51	53	30
Y	74	52	51	87	47	58	58	32	73
Zr	622	521	272	663	423	177	194	126	660
Nb	38	28	29	40	32	27	24	15	39
Th	22	18	17	22	23	17	18	17	22
Pb	15	12	5	18	10	4	11	9	7
Ga	24	24	25	28	25	22	26	23	23
Zn	41	46	44	45	42	22	63	28	37
Cu	ND	ND	1	ND	ND	ND	ND	ND	ND
Ni	54	37	34	58	32	42	39	23	36
V	2	20	26	15	9	0	15	7	7
Cr	23	25	25	15	22	21	22	32	29

ND - Not Detected

TABLE 3
MAJOR- AND TRACE-ELEMENT ANALYSES OF MAFIC VOLCANIC ROCKS
OF THE CAMERON MOUNTAIN FORMATION

	13A	43A	99	114	120	83B	187B	318B	12A	25	31
SiO_2	46.37	47.58	45.75	46.23	46.46	47.73	47.71	48.69	48.24	48.06	43.25
TiO_2	1.33	1.88	1.37	1.20	1.21	3.92	3.67	1.41	1.77	1.26	1.48
Al_2O_3	16.59	16.53	16.77	17.16	15.67	13.15	13.66	15.17	16.02	15.68	15.85
Fe_2O_3	10.61	11.40	9.29	9.67	10.27	15.23	15.09	10.00	10.56	8.46	8.97
MnO	0.18	0.15	0.13	0.14	0.15	0.20	0.24	0.17	0.16	0.16	0.14
MgO	9.08	7.23	5.69	8.09	7.38	4.96	4.62	7.75	6.81	6.46	4.70
CaO	6.91	6.84	10.53	11.38	10.80	5.42	6.28	7.31	6.61	10.53	13.50
Na_2O	3.47	3.64	3.00	2.18	3.43	2.04	3.66	3.63	3.54	3.42	3.37
K_2O	0.67	0.30	1.09	0.20	0.07	0.90	0.21	0.19	1.37	0.54	0.33
P_2O_5	0.12	0.23	0.21	0.16	0.17	0.79	0.81	0.17	0.20	0.19	0.15
L.O.I.	4.6	4.4	7.0	3.1	4.4	6.4	3.3	6.0	4.6	6.0	9.8
Ba	157	100	82	69	9	172	431	149	164	102	48
Rb	13	0	17	3	ND	29	ND	0	30	3	4
Sr	382	397	225	181	177	148	324	211	150	166	360
Y	26	29	22	22	21	64	54	24	30	25	27
Zr	93	146	106	80	95	399	286	108	126	95	93
Nb	4	7	7	6	5	22	16	7	5	7	5
Th	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pb	ND	ND	ND	ND	2	ND	3	ND	ND	ND	ND
Ga	20	20	19	19	20	31	23	25	18	13	16
Zn	80	89	94	81	67	185	140	82	96	74	80
Cu	41	21	7	39	99	63	18	20	41	27	43
Ni	38	42	32	44	57	34	25	33	108	71	144
V	230	266	221	219	205	396	388	255	259	247	208
Cr	180	149	284	291	340	8	34	258	249	258	275

ND - Not Detected

TABLE 3 (CONCLUDED)

	54	160	196	198	280	86	205	218E	222B	329	331A
SiO_2	46.64	47.01	42.95	50.86	50.47	46.86	48.15	47.31	44.30	49.41	48.89
TiO_2	2.23	2.62	2.30	3.56	1.68	2.15	1.75	4.00	1.93	1.25	1.75
Al_2O_3	16.65	16.03	15.72	15.03	15.86	15.72	18.41	13.20	16.68	16.37	15.52
Fe_2O_3	12.01	11.02	10.83	12.03	9.92	11.16	11.49	16.30	11.92	8.55	9.70
MnO	0.12	0.20	0.19	0.17	0.16	0.17	0.15	0.19	0.16	0.13	0.15
MgO	5.55	8.23	5.16	3.69	7.78	7.30	6.88	3.52	6.11	6.70	7.02
CaO	10.35	7.56	9.94	3.82	5.97	8.64	2.06	5.35	7.03	9.29	7.55
Na_2O	2.42	2.75	3.24	4.24	2.77	2.71	4.94	4.06	3.53	3.51	3.88
K_2O	0.35	0.16	0.66	1.71	0.58	0.26	0.57	0.88	0.40	0.65	0.18
P_2O_5	0.27	0.31	0.32	0.93	0.17	0.30	0.20	0.88	0.28	0.13	0.20
L.O.I.	2.9	4.8	10.1	3.3	4.7	4.7	5.3	4.1	8.6	4.0	5.1
Ba	59	122	127	525	79	182	168	330	1062	155	52
Rb	4	ND	15	26	7	4	31	12	9	20	2
Sr	336	356	292	463	214	750	191	387	550	564	67
Y	31	37	35	58	28	32	30	91	30	26	29
Zr	181	101	174	317	104	170	107	447	148	86	115
Nb	9	10	10	21	4	9	5	17	11	5	5
Th	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
Pb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ga	20	24	20	28	13	21	12	28	18	16	16
Zn	95	116	91	135	94	99	108	163	98	78	91
Cu	35	85	41	32	45	34	3	28	10	60	17
Ni	73	65	59	13	181	89	142	15	64	127	109
V	278	337	321	347	275	231	265	343	288	229	277
Cr	81	159	147	21	459	216	386	29	297	300	319

ND - Not Detected

Member (Unit Dcf_1) of the Cameron Mountain Formation. Upper and lower contacts were not observed, except in a poorly exposed section in the ditch along Route 380 north of Blue Bell Mountain where approximate contacts could be inferred. Here, polymictic conglomerate (Figure 13) constitutes less than half of the estimated thickness of 100 m, and related purple to red or maroon terrestrial sandstones and siltstones are well represented. This unit apparently reflects a regressive transition from marine sedimentation to terrestrial conditions prior to the onset of volcanism, and may include both terrestrial and shallow marine deposits.

Typically, the Polymictic Conglomerate Member is observed in isolated outcrops where no estimate of total unit thickness can be made. It is possible that these beds pinch and swell, and locally may be absent from the record. Closely spaced outcrops on the CNR track southeast of Graham Brook indicate a minimum section thickness of 30 m. These outcrops contain terrestrial reddish sandstone, siltstone, and conglomerate interbedded with grey-green to pale green sandstone and siltstone that may represent shallow marine deposition. Two outcrops northwest of Cameron Mountain consist of red-brown, fairly coarse polymictic conglomerate with local thin interbeds of red grit. The largest of these outcrops exposes a stratigraphic thickness of about 30 m.

Clasts in these rocks include felsic and mafic volcanic fragments (the source of which is no longer exposed or is totally eroded), pelitic and quartzose sedimentary clasts, and quartz and feldspar grains. Clay matrix is generally a very minor component, and limonite and hematite are typical cements with up to 20% hematite in some samples. Most clasts are subrounded and rarely exceed 1.5 cm in diameter.

Lower Felsic Member (Unit Dcf_1): The Lower Felsic Member underlies a series of steep-sided resistant hills and ridges including Blue Bell, Burnt Hill, Cameron, and Geneau mountains in the southwestern part of the map area.

This unit consists of flow-banded rhyolites (Figure 14), felsic pyroclastics, local interbedded volcanogenic (epiclastic) sedimentary rocks, and minor mafic flows. Rhyolite flows are white-weathering, aphanitic to porphyritic, typically flow-banded and pink, buff, or grey to green in colour. Flow banding is usually well defined in very thin, discrete layers often less than 1 mm thick, but may be subtle, especially in the thicker, slightly porphyritic flows. Banding is defined by variations in grain size, primary or secondary (i.e., devitrification) textures, and locally by concentrations of opaque minerals. Flow structures are less commonly defined by a pilotaxitic texture of feldspar laths in a vitric groundmass. Intricate flow folding is developed locally, and vesicular horizons were seen at a few localities.

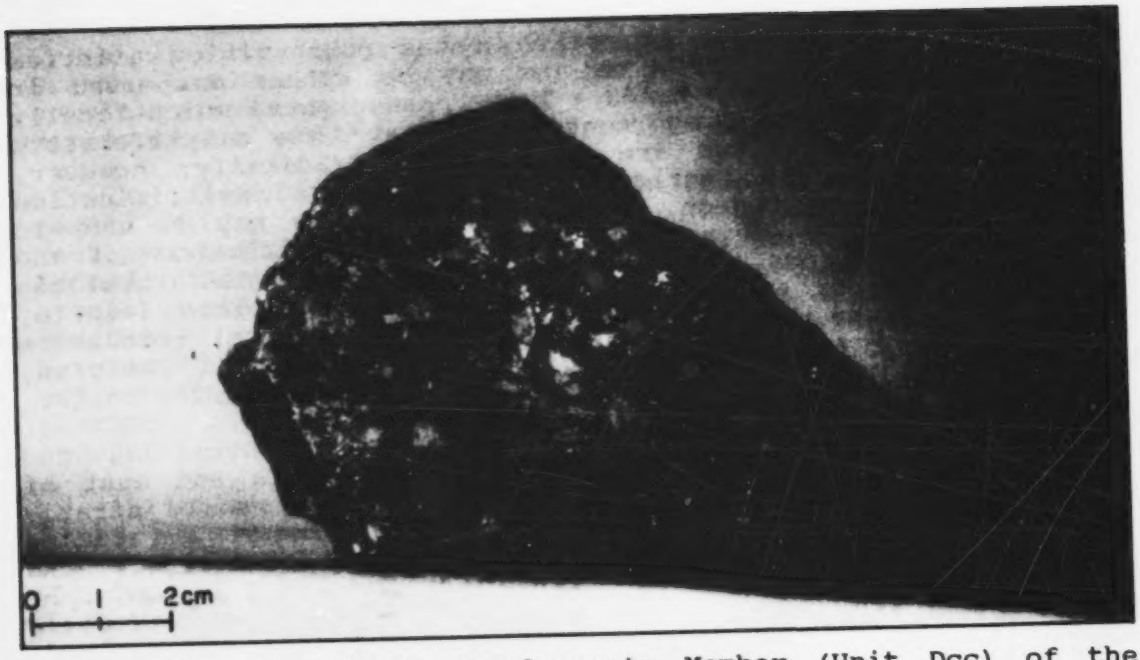

Figure 13. Polymictic Conglomerate Member (Unit Dcc) of the Cameron Mountain Formation, on Route 380 near Blue Bell Mountain.

Figure 14. Flow-banded rhyolite from the Lower Felsic Member (Unit Dfv_1) of the Cameron Mountain Formation, from locations on the highway south of Geneau Mountain and from the top of Cameron Mountain.

Pink-orange feldspar crystals in the porphyritic varieties vary in size from 1 to 4 mm and may be either dispersed or concentrated in discrete bands. These phenocrysts, which locally form glomeroporphyritic aggregates, are set in a cryptofelsitic groundmass. Spherulites are seen only sporadically; however, patchy, irregular to lenticular or ribbon-like devitrification patterns are very common. The latter feature may be due to variations in rate, degree, or timing of devitrification of the original homogeneous rhyolite. Mineralogically, the rhyolites consist of quartz + potassium feldspar ± plagioclase (albite, oligoclase) ± opaques (hematite, pyrite, or limonite) ± chlorite ± white mica ± zircon ± apatite ± calcite ± sphene. Vesicles, where present, are filled with chlorite, calcite, and/or quartz.

Pyroclastic rocks, which include ash-flow, ash-fall, and agglomeratic lapilli tuffs, are most common south and east of Cameron Mountain. Ash-flow tuffs are typically poorly stratified and partly welded; flattened pumice fragments and fiammé form definite but relatively weak eutaxitic textures. One exposure of tuff on the highway east of Hazeldean consists of rounded to ovoid spherulitic clasts. Apparently, devitrification of the original glassy rock occurred before fragmentation, probably in a vent or near-vent environment. In addition to pumice fragments, ash-flow tuffs consist of quartz crystals, altered subhedral feldspar crystals, a few mafic clasts, and rare spherulitic and axiolitic relict glass shards in a devitrified cryptofelsitic groundmass.

An olive-green, stratified tuffaceous rock cropping out east of Cameron Mountain has been interpreted as an ash-fall tuff. It contains a large, dark green, felsic to intermediate lapilli mantled by fine-grained ash. On Route 380 northeast of Blue Bell Mountain, a pink, crudely stratified pyroclastic rock containing rhyolitic fragments, green pumiceous ash and angular feldspar fragments is also thought to be an ash-fall tuff. In an outcrop southeast of Cameron Mountain, a fragmental rock containing lapilli-sized, subrounded rhyolitic clasts, green pumiceous material and orange alkali-feldspar crystals probably represents agglomeratic fallout in a near-vent environment.

Red to purple or maroon conglomerate, sandstone, and siltstone are locally interbedded with the volcanic rocks. Good exposures are found on Route 380 northeast of Blue Bell Mountain and at the upper contact of the Lower Felsic Member where it crosses the power line 1 km northwest of Crombie Settlement. These are mainly volcanogenic sediments deposited as an epiclastic facies of the volcanic sequence. However, some beds contain sedimentary rock fragments and are more accurately termed polymictic conglomerates or lithic sandstones.

An isolated outcrop of pillowed basalt was observed east of Graham Brook. It appears to be interbedded with the felsic volcanic rocks but may be contiguous with the Mafic Volcanic Member to the west. Exposure is poor here.

The lithologies present within the Lower Felsic Member record mainly subaerial conditions. Flow-banded rhyolites and most pyroclastic rocks were deposited subaerially, whereas interbedded pillow basalt and volcanogenic sedimentary rocks are probably shallow-water deposits. Identification of vents or conduits is largely conjectural due to limited exposure. However, thickening of the lower member near Cameron Mountain and the presence of coarse pyroclastic material typical of proximal facies deposits suggest that a vent may have been located in this vicinity.

Attitudes of primary flow layering in the Lower Felsic Member conform to and reflect the anticlinal structure that controlled the distribution of the unit. Dips are fairly shallow (25°) at the nose, and vary from 30° to 85° on the limbs. The thickness of this unit varies from an estimated 300 m on the western limb, to 700 m in the "nose" area to the north, and to 400 m on the eastern limb.

Mafic Volcanic Member (Unit Dcm): Mafic extrusive rocks overlying the Lower Felsic Member of the Cameron Mountain Formation are exposed in the southwestern portion of the map area within a tight elliptical arc that is truncated by the Blue Bell Fault. These rocks are best exposed in a long and deep CNR railway cut at Graham Brook east of New Denmark (Figure 15).

The lithologies of this unit record submarine conditions, and include green, dark grey, and purple-maroon, massive to pillowed basalts (Figure 15), amygdaloidal or vesicular basalts (Figures 16 and 17), hyaloclastites (Figure 18), minor tuffs, local interbedded felsic to intermediate volcanic rocks and calcareous quartzose sediments. Rarely, xenoliths of dark grey hornfelsed siltstone are observed in the basalt. The western "limb" of the Mafic Volcanic Member consists almost entirely of pillow basalt; hyaloclastites, tuffs, and light green amygdaloidal flows are essentially restricted to the eastern "limb". Dark grey, purple-maroon, and olive to dark green massive basalts are interbedded in arbitrary fashion.

The thickness of this unit, based on an average dip of 45° and a northerly plunge of 25°, varies from about 300 m on the west side to about 1 km on the north and northeast and to about 600 m on the east where it interfingers with and is overlain by the Upper Felsic Member.

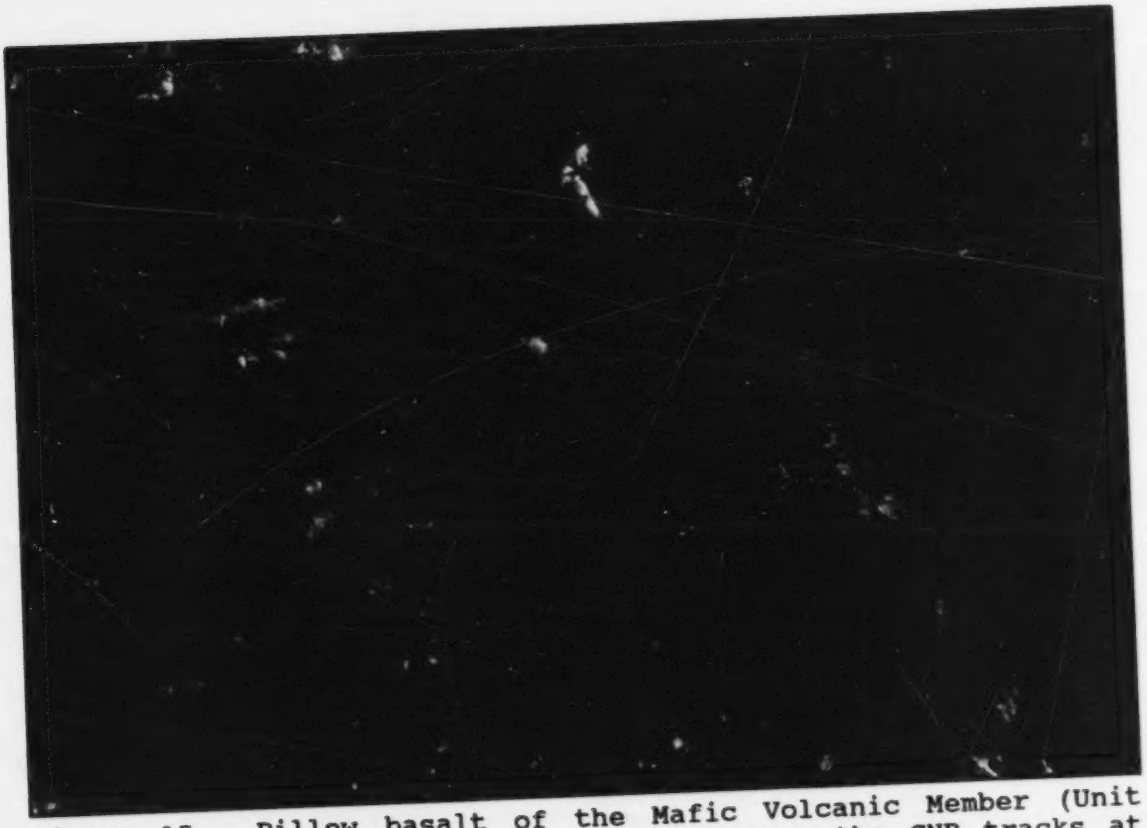

Figure 15. Pillow basalt of the Mafic Volcanic Member (Unit Dcm) of the Cameron Mountain Formation along the CNR tracks at Graham Brook.

Figure 16. Vesicular basalt of the Mafic Volcanic Member (Unit Dcm) of the Cameron Mountain Formation from a location on the power line 800 m north of Crombie Settlement.

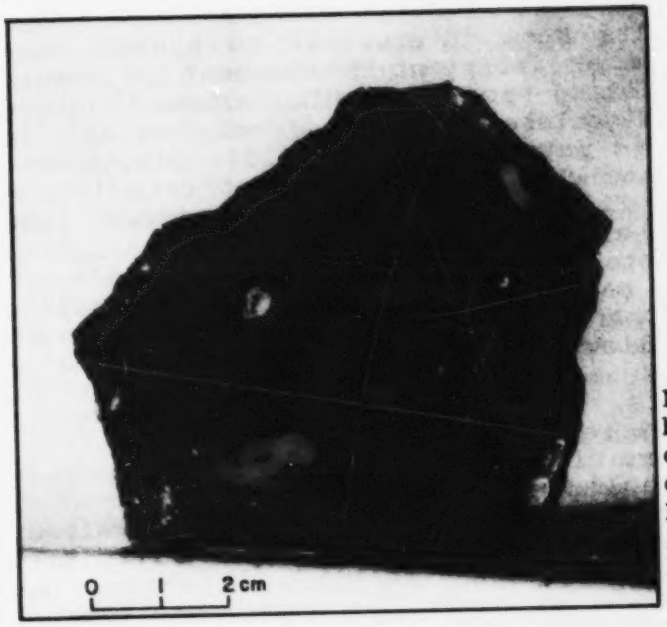

Figure 17. Amygdaloidal basalt of the Mafic Volcanic Member (Unit Dcm) of the Cameron Mountain Formation, from a location 100 m southeast of sample location 218E (Plate 89-72(R)).

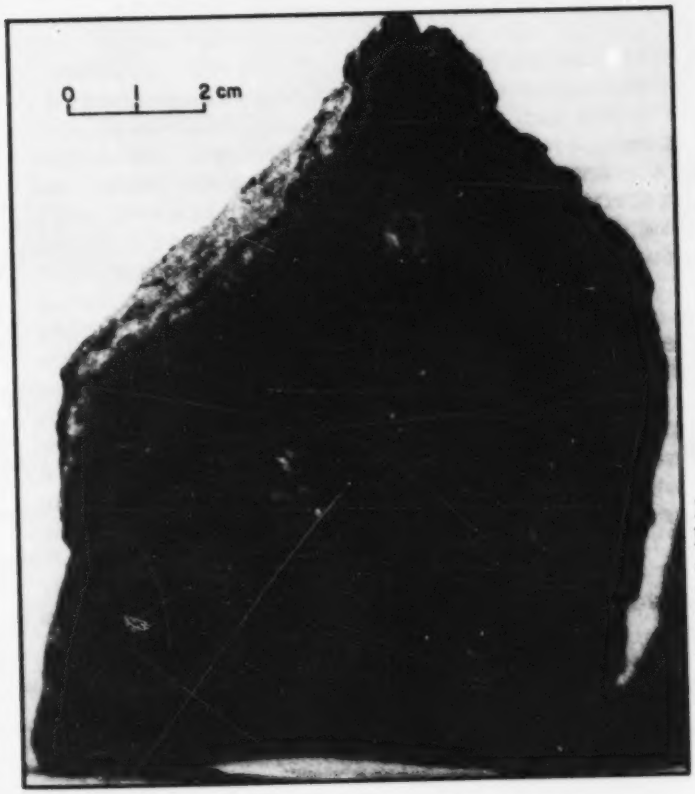

Figure 18. Hyaloclastic breccia of the Mafic Volcanic Member (Unit Dcm) of the Cameron Mountain Formation, from a location about 400 m west of sample site 261A (Plate 89-72(R)), where it is in contact with the Upper Felsic Member (Unit Dcf_2).

In thin section, basalts show intersertal to hyalopilitic textures; locally, there is an incipient development of variolites consisting of radiating acicular plagioclase. Sodic plagioclase (albite or oligoclase), though fresh-looking, is normally the result of sodic metasomatism of calcic plagioclase (spilitization). Calcite and chlorite are abundant both in the groundmass and as vesicle fillings; chlorite is an ubiquitous alteration product of a glassy basaltic groundmass. Other constituents include epidote, brown turbid sphene apparently derived from alteration of basaltic glass, and opaque minerals, including ilmenite. In one outcrop, manganese nodules were observed in a brecciated pillow lava.

In less altered basalts, fresh augite is usually present, and plagioclase is much more calcic (An_{54}-An_{64}:labradorite). Textures are intergranular, locally vesicular, and sparsely porphyritic, with plagioclase phenocrysts up to 2 mm in size. Some of the thicker flows of this type become coarse grained, with diabasic textures. Typically, labradorite has been replaced to some degree by calcite, although epidote, prehnite and chlorite are also minor alteration products. Augite, in places, is partially replaced by chlorite, epidote, calcite, and/or prehnite. Interstitial chlorite is ubiquitous. Opaque minerals include pyrite (square or rhombic cross sections), magnetite, hematite (reddish coloration), and skeletal ilmenite.

Hyaloclastic tuffs and breccias typically contain altered, fine-grained, subrounded to subangular, pilotaxitic fragments in an altered, hyalopilitic groundmass of mafic granules, basaltic glass, plagioclase microlites, and very fine grained felsitic fragments. Cavity fillings consist of chlorite and calcite; small plagioclase phenocrysts are common. Local felsitic clasts may have been derived from underlying felsic volcanic rocks through which feeder vents for the mafic lavas must have passed.

Minor green to maroon, massive to flow-banded, aphanitic, felsic to intermediate volcanic rocks are interbedded with mafic flows north of Cameron Mountain. One outcrop along the power line near the Denmark-Lorne parish boundary contains elaborately flow-folded and brecciated rhyolite that probably reflects subaerial rather than submarine deposition. These rocks are similar to rhyolites in the Upper Felsic Member of the Cameron Mountain Formation, which crop out farther south along the same power line.

Sedimentary rocks interbedded with the mafic volcanic rocks are typically dark blue-grey, massive, calcareous, fossiliferous quartzose siltstones and fine-grained sandstones. These horizons are not depicted on Plate 89-72(R). Identifications made by Boucot (written communication, 1987) of sparse fauna in these

beds (GSC 101919) include Coelospira sp., Metaplasia, ambocoelid, dalmanitid, dalmanellid, and a tetracoral. This assemblage was assigned an Early Devonian age based primarily on the presence of the ambocoelid. Fossils collected from sedimentary rocks interbedded with mafic volcanic rocks northeast of Cameron Mountain (GSC 98614, 101926) include Amsdenina sp., Anastrophia sp., Atrypa "reticularis", Cypricardinia sp., Cyrtina sp., Dalejina (?) sp., Gypidula coeymanensis, Gypidula sp., Howellella(?) sp., Isorthis sp., Leptaena "rhomboidalis", Levenea sp., Megakozlowskiella sp., Meristina sp., Nanothyris sp., Nucleospira sp., Strophonella euglypha, a brachiopod, orthotetacid, phacopids, rhynchonellids, and a tetracoral indicating an early to mid-Helderbergian (Gedinnian) age.

Upper Felsic Member (Unit Dcf_2): The Upper Felsic Member of the Cameron Mountain Formation overlies and interfingers with the Mafic Volcanic Member (Unit Dcm) east of Cameron Mountain and north of the Blue Bell Fault. It comprises mainly pink to reddish-pink, massive aphanitic rhyolite that is locally autobrecciated. However, it includes minor flow-banded, flow-folded, and brecciated aphanitic rhyolite, green pillow basalt, quartzose sedimentary rocks, and volcanogenic conglomerate. These deposits are primarily submarine, although the flow-banded, flow-folded, and brecciated rhyolites may be subaerial deposits.

Massive to autobrecciated aphanitic rhyolites are characterized by cryptofelsitic textures and thin lenticular bands of granular, "mosaic" quartz; no phenocrysts are present. Locally, in outcrop, a crude flow layering can be identified roughly parallel to lenticular pillow-like features apparently related to submarine deposition. Cross-cutting quartz veinlets and stringers are common. Flow-banded and flow-folded rhyolites, lying just above the contact with the Mafic Volcanic Member along the power line northeast of Crombie Settlement, feature alternating bands of pink and green flows. Massive pink-brown rhyolite in the same outcrop contains rounded clasts of green mafic to intermediate material. Farther north along the same stratigraphic horizon, on the haulage road just east of the power line, green mafic flows and breccias contain numerous clasts of pink devitrified rhyolite with relict perlitic cracks.

Other lithotypes within this unit are present as isolated outcrops that include an andesitic to dacitic fragmental volcanic rock; conglomerate consisting of coarse angular volcanic detritus; dark grey-green, massive, calcareous, fine-grained sandstone; and a thick flow of locally pillowed basalt with coarse diabasic texture.

Blue Mountain Rhyolite (Unit Db)

The Blue Mountain Rhyolite forms a lenticular belt situated on the western slope of Blue Mountain, along the eastern margin of the survey area. The unit consists of mainly red, red-brown or maroon, flow-banded, massive to porphyritic ferruginous rhyolite. At the northern extent of this belt along the Tobique River, red to maroon hematitic rhyolite is interbedded with grey to green rhyolite, pink-brown to maroon tuffaceous siltstone, pillow basalt, and strongly altered and hematitized mafic volcanics. The grey to green rhyolite is characterized by hematite-filled fractures; this and the leaching and hematitization of some of the mafic volcanics appear to be the product of epithermal alteration.

In thin section, the predominant maroon flow-banded rhyolites feature a turbid, ferruginous, cryptofelsitic groundmass that exhibits a ragged "jigsaw" mosaic style of devitrification, with individual quartzofeldspathic patches from 0.1 to 0.5 mm in size. Most of these rhyolites are sparsely porphyritic with up to 15% orthoclase crystals 0.3 to 3.0 mm in size. Crystals are euhedral, equidimensional to prismatic (blunt or elongate), typically oriented obliquely to flow-banding, sometimes broken, variably altered to sericite, and often turbid with inclusions. Hematite content is difficult to estimate, but probably averages about 5%. Hematite occurs as dark grey aggregates that are easily visible in hand specimen and as finely disseminated dust-like grains that contribute to the red-maroon colour of the rock and the turbid appearance in thin section.

Wapske Formation (Unit Dw)

Sedimentary rocks of the Wapske Formation comprise the greater portion of the Tobique Group section, underlying most of the central and northeastern portions of the survey area in a broad zone between the Blue Bell and Rocky Brook-Millstream faults, as well as a narrow belt extending to the southwestern corner of the map area. In addition, two fault-bounded blocks extend from either side of the main belt, one at North View between the North View and Sisson Ridge faults, and one along Salmon River between the Salmon River, Foley Brook, and Rocky Brook-Millstream faults (Figure 19).

Lithology: The sedimentary lithotypes and facies of the Tobique Group are very similar on a regional scale, although local variations are present (St. Peter 1978b, 1979; Pickerill 1986). Grey to green siltstone interbedded with varying proportions of grey to green, fine- to medium-grained sandstone are by far the most common sedimentary facies. For convenience, this lithofacies can be subdivided into sand-dominant and silt/mud-dominant subfacies. However, because there is no

Figure 19. Interbedded sandstones and siltstones of the Wapske Formation (Unit Dw), exposed along the CNR track near Salmon River.

systematic lateral or vertical pattern in the distribution of these subfacies, they cannot be mapped out as discrete members within the stratigraphic succession. This suggests that there was no significant spatial or temporal variation in the depositional environment of Lower Devonian sedimentary rocks within the survey area.

Sandstones comprising the sand-dominant subfacies are typically grey to green, fine- to medium-grained, micaceous, noncalcareous to weakly or moderately calcareous, and weathered grey to brown depending on the carbonate content of the rock. These sandstones vary from quartzose to arkosic arenites, according to the scheme of Blackburn et al. (1978). Bed thickness ranges from 1 cm to 1 m, but commonly is between 5 cm and 30 cm thick. Parallel laminations (Figure 20) and, to a lesser extent, wave or current-ripple cross laminations (Figure 21) are the most common bedforms developed. Parallel lamination, as expressed in thin sections, is defined by slight changes in grain

Figure 20. Parallel-laminated sandstone of the Wapske Formation (Unit Dw) exposed on a logging road at the headwaters of Sutherland Brook. Note the concentrations of fine-grained organic detritus along bedding planes.

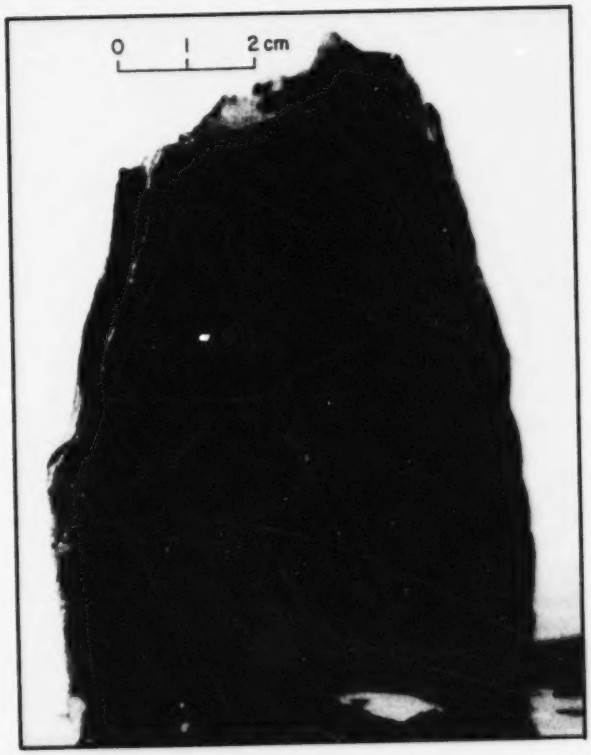

Figure 21. Wavy and cross-laminated sandstone of the Wapske Formation (Unit Dw), exposed on a logging road near a tributary of Padget Brook, about 1.7 km west of the Haley Brook Fault.

size or mineralogy; even in apparently massive beds, aligned flakes of muscovite or parallel linear concentrations of opaque minerals or organic detritus often indicate primary layering. Load casts, ripple marks, bioturbation and graded bedding have been seen in only a few outcrops. Post-depositional, soft-sediment deformational features noted in some thin sections include microshears oblique to bedding planes, and dewatering structures that disrupt sandstone/siltstone interfaces.

Detrital grains are typically well sorted, closely packed, subangular to subrounded, and range from 0.05 to 0.20 mm in size. Calcite, limonite, hematite, and authigenic quartz are common cementing materials. The sandstone consists of quartz (35-65%), plagioclase (absent in some quartzose sandstones, up to 60% in arkoses, typically with some degree of calcite and/or sericite alteration), muscovite (2-5%), calcite (up to 25%), minor clay minerals, zircon, sphene, apatite, opaque oxides, and local lithic fragments (up to 10%). In some rocks, limonite or hematite accounts for up to 20% of the rock, imparting a yellow-brown, pink-brown, or reddish coloration.

Only two types of sandstone observed in the survey area are sufficiently different from the generalized description given above to warrant special mention. The first is a grey, medium- to coarse-grained, thin- to medium-bedded micaceous quartzose sandstone that often takes on a "flagstone" appearance due to regular 2 to 5 cm partings along parallel laminations or bedding planes. Comminuted plant debris is usually associated with this type of sandstone, suggesting that it may have been deposited in relatively shallow water. A narrow horizon of this sandstone crops out in the northeast portion of the map area, parallel to Blue Brook and Giberson Brook, as far southwest as Left Hand Branch Two Brooks. The second distinctive type is a pale grey, pink to yellow-brown or red-brown weathered(?), fine-grained sandstone or siltstone. These rocks are exposed mainly within two narrow horizons, one parallel to the western fault margin of the North View horst, and the other in the northeast portion of the survey area along the Haley Brook Fault between Haley Brook and Right Hand Branch Two Brooks. The typical pink to brown colour is imparted by limonite or hematite, which may have originated from oxidation subsequent to deposition or from iron alteration associated with fluid migration in nearby faults.

In the silt/mud-dominant subfacies, grey to green siltstones may be massive or contain laminations or thin to medium beds of sandstone lithologically identical to those occurring in the sand-dominant subfacies. The petrography of these siltstones is variable. Green siltstones are typically argillaceous, very friable and massive, although thin, brown-weathered beds or

parallel laminations of fine-grained sandstone may be present locally. Beds of green shale or mudstone are frequently associated with green siltstone. Grey siltstones (gradational to slates and fine-grained grey sandstones) are much more competent than green siltstones due to a higher quartz component, and are mineralogically similar to sandstones of the sand-dominant subfacies. They are commonly micaceous, parallel laminated, and thin to medium bedded (up to 10 cm, with rare beds of 30 cm thickness). Sandstone beds or laminations are easily recognized by their characteristic buff-brown weathering, especially where they are calcareous. Aside from parallel lamination, small-scale wave or current-ripple cross laminations are the most common bedform developed in these sandstone intervals, whereas low-angle trough cross laminations are relatively uncommon.

Age and Paleoenvironment: Faunal assemblages collected from several outcrops have established a Helderbergian (Early Devonian) age for sedimentary rocks of the Wapske Formation. These outcrop locations are indicated on Plate 89-72(R) by their GSC identification numbers. Fossil identifications submitted by A.J. Boucot (written communication, 1982, 1987, 1988) are as follows: GSC 98622 - Megakozlowskiella sp., Dicoelosia sp., Isorthis sp., platyceratis, trilobite, Levenea(?) sp., Macropleura cf. macropleura, Leptaena "rhomboidalis", Meristella; GSC 101928 - Discomyorthis(?) sp., Dicoelosia sp., unidentified brachiopods, isorthid(?); GSC 101930 - Orthostrophia(?) sp., many Dicoelosia sp., Plicanoplia(?) sp., Dalejina(?) sp., Atrypina(?) sp., Megakozlowskiella sp., Leptaenisca(?) sp., Leptaena "rhomboidalis", Odontochile cf. micrurus (trilobite identification by P.J. Lespérance, written communication, 1987); GSC 103062 - Discomyorthis sp., Costistrophonella punctulifera, Megakozlowskiella sp., Leptaena "rhomboidalis", Mesodouvillina(?) sp., plethorhynchid, fenestellid, stropheodontid, and unidentified brachiopods; GSC 103064 - Dawsonelloides sp., Prorensselaeria, Zygobeyrichia, Craniops sp., Tentaculites sp., Concinnispirifer sp., homalonatid, bivalves, bryozoans.

These fossil localities contain mainly brachiopods, with fewer representatives of bryozoans, crinoids, trilobites, etc. However, in two separate outcrops of grey siltstone in the North View fault block, the imprint of cephalopod (nautiloid) shells was discovered (Figure 22). No identification was possible because only a small part of any specimen could be recovered. The original size of one nautiloid was estimated from the arc of its spiral to be about 15 to 20 cm in diameter.

The lithofacies of the Wapske Formation observed in the survey area are strikingly similar to various facies within the "shallow marine siliciclastic lithofacies" of Johnson (1978).

Figure 22. Partial impression of cephalopod (nautiloid) shell in siltstone of the Wapske Formation (Unit Dw), from a small stream 1 km east of North View.

Parallel- and cross-laminated, fossil-poor sandstones appear to correlate with Johnson's Sandstone Facies, whereas the sequences of thin- to medium-bedded siltstones and sandstones comprising much of the Wapske Formation resemble his Heterolithic Facies, consisting of "sand-dominated, mixed, and mud-dominated subfacies". Four specific correlations can be drawn between the Wapske Formation and Johnson's Heterolithic Facies: (1) sandstone beds in the "sand-dominated" subfacies are generally thicker than those in the "mixed" and "mud-dominated" subfacies (5-20 cm versus 3-10 cm); (2) considerable lithologic variability is evident in the stratigraphic record, reflecting fluctuations in sediment supply and wave and current regimes; (3) rich fossil horizons occur at the base of some sandstone beds, probably reflecting transportation and accumulation during high-energy or storm conditions; (4) local, rich, trace fossil assemblages are present (trace fossils have been noted in a few outcrops and are very abundant in a sequence of thinly interbedded sandstones, siltstones, and shales near Riley Brook, a short distance east of the northeast corner of the survey area). Sequences of thin

(1-3 cm) graded beds of silt and shale noted in some outcrops closely resemble descriptions of beds occurring in Johnson's (1978) Mud Facies.

Many sandstone beds also resemble the storm-related "sublittoral sheet sandstones" of Goldring and Bridges (1973) or "storm-lag" deposits of Brenner and Davies (1973). For example, sandstones are well-sorted, fine- to medium-grained, and interbedded with mudstone and siltstone; parallel lamination is the dominant internal bedform, and beds are generally 5 to 30 cm thick.

St. Peter (1978b, 1979) has interpreted a relatively shallow marine shelf environment for the Wapske Formation to the southeast of the survey area on the basis of faunal communities and primary sedimentary structures. Fossil assemblages identified by Boucot (in St. Peter 1979) were said to be representative of quiet water Benthic Assemblage 3 (Boucot 1975), and could be designated a Mutationella community. Shallow marine conditions were also interpreted from the presence of the trace fossil Isopodichnus (R.K. Pickerill, personal communication to C. St. Peter; in St. Peter 1979). However, near Perth-Andover to the south of the survey area, Pickerill (1986) has suggested deposition below storm wave base in an outer shelf/upper slope environment on the basis of internal bedforms and the presence of transported rather than in situ fauna.

Boucot (written communication, 1987, 1988) has assigned most fossil assemblages listed in this section to Benthic Assemblage 3 (Boucot 1975) with rare examples of Benthic Assemblage 4 to 5 communities. The upper depth limit proposed by Boucot (1975) for Benthic Assemblage 4 to 5 is 183 m (600 ft), which corresponds with the upper limit of 200 m for the "shallow siliciclastic seas" of Johnson (1978).

Contacts and Thickness: The base of the Wapske Formation within the survey area is not exposed; however, it is assumed to conformably overlie the Cameron Mountain Formation. The Wapske Formation is juxtaposed against older units along the Rocky Brook-Millstream, Salmon River, and Foley Brook faults, and original contacts have been obliterated. The Wapske Formation is typically in fault contact with the Mississippian Arthurette Redbeds (Unit Ma) along the Blue Bell Fault; however, the Arthurette Redbeds unconformably overlie the Wapske Formation in the extreme southern portion of the map area.

The Wapske Formation section between the Blue Bell and Rocky Brook-Millstream faults dips fairly consistently to the west, and represents the west-dipping limb of a major fold that has been truncated on the east by the Blue Bell Fault. Except for

local small-scale parasitic folds, the only fold axes in the survey area are located near the Rocky Brook-Millstream Fault. Taking this into account, northwest-southeast structural cross sections through the centre of the map area suggest a thickness of about 8000 m for the sedimentary rocks lying between the Blue Bell and Rocky Brook-Millstream faults. In the type area of the Tobique Group, located about 20 km east of the eastern boundary of the map area, St. Peter (1978b) estimated thicknesses of 2900 m and 8000 m for west-dipping volcanic and sedimentary rocks of the Costigan Mountain Formation and Wapske Formation, respectively. The intervening area is characterized by numerous minor folds that are responsible for an undetermined amount of structural repetition, so that the total thickness of either the Tobique Group or its constituent sedimentary rocks cannot be reliably estimated.

MAFIC INTRUSIVE ROCKS (UNIT Dm)

Mafic intrusive rocks occur as small gabbroic stocks or plugs adjacent to the Rocky Brook-Millstream Fault, and as numerous diabasic to gabbroic dykes intruding mainly Devonian sedimentary rocks. Exposure is very poor in the north-central portion of the survey area where the mafic stocks are located and, for the most part, the contacts as shown on Plate 89-72(R) have been interpreted from their aeromagnetic signatures. The gabbro is typically medium to dark green and medium grained; however, there are two exposures of fine-grained, vesicular mafic rocks near lithogeochemical sample location ND-18 and ND-27 (Plate 89-72(R)) that would normally be mapped as basalts. The anomalous textures of these assumed intrusive rocks are interpreted to be due to reaction of mafic magma with water-laden sedimentary country rocks. As shown on Plate 89-72(R), large (apparent) roof pendants lie within the two largest stocks, evidence that some sediment-magma reaction has probably occurred. The intrusive contact is rarely seen but is characterized in places by the development of a narrow hornfelsed zone in the host sedimentary rocks.

In thin sections, the gabbros are highly altered and show intergranular to subophitic textures. Constituent minerals include albitized plagioclase (50-60%), augite (up to 20%), chlorite (up to 33% in more altered samples), and opaques (3-4%). Calcite, actinolite, and biotite are abundant in some samples; quartz is rarely present. Interlocking laths of albite, which are typically partially replaced by sericite or rarely by calcite, average 0.5 mm in length and do not exceed 2.5 mm. Augite occurs as equant prismatic groundmass granules (0.1-0.4 mm), elongate prisms (up to 0.8 mm) or as larger crystals up to 4 mm in size that may enclose plagioclase laths.

Augite has been replaced to varying degrees by fibrous aggregates of chlorite and/or actinolite; where alteration is intense, only 1 to 2% small relict grains of augite may remain. Chlorite and calcite are locally present in small vesicles.

Mafic dykes intrude sedimentary rocks of the Matapédia and Tobique groups near the Salmon River and Rocky Brook-Millstream faults in the western part of the survey area, and are most common within the fault block at North View. In the Matapédia Group, dykes are typically 1-2 m wide, but reach much greater widths in sedimentary rocks of the Wapske Formation. At one outcrop on a logging road on the north side of Foley Brook, about 70 m of grey-green diabase was measured normal to regional strike; however, contacts are buried and this may not be a true width.

The mafic dykes are highly altered, frequently plagioclase- and/or augite-phyric diabases and gabbros. Original textures range from intergranular to ophitic and are normally preserved by secondary mineralization. Plagioclase, both as phenocrysts and matrix laths, is in all cases albitized and replaced to various degrees by sericite and local carbonate. Typically, plagioclase laths (0.2-0.6 mm in size) constitute 50-60% of the rock, although content may be as low as 35%. Plagioclase phenocrysts are up to 3 mm in size and comprise up to 20% of some rocks; one sample contained crystals up to 1 cm long. Augite generally occurs as small phenocrysts or interstitial grains up to 0.5 mm in size, in amounts up to 15%. Where augite is more abundant (15-30%), it is in the form of large phenocrysts and poikilitic grains up to 5 mm in size. Actinolite, chlorite, and (locally) epidote contents vary depending on the extent of alteration of interstitial augite or other mafic phases. In two samples, epidote (2%) and actinolite (10%) completely replaced grains having forms indicative of olivine. Calcite (0-20%) occurs as patches, up to 3 mm in size, that replaced plagioclase or mafic minerals. Opaques are typically present in accessory amounts (2-4%), and sphene was noted in two samples.

STRUCTURAL GEOLOGY

FOLDING AND CLEAVAGE

The Lower Paleozoic rocks of the survey area have been affected by a single episode of compressive deformation, producing a northeast-trending, incipient to well-developed fracture or slaty cleavage. Rare kink bands fold this cleavage. Contrasting styles of folding are evident between the Aroostook-Matapédia and Tobique zones (Figure 1), apparently due

to competency differences between their respective constituent lithotypes. In the Aroostook-Matapédia Zone, precleavage northwest-trending folds have been interpreted from local anomalous structural trends. It has been suggested (Rast et al. 1980) that macroscopic pre-Acadian-deformation folds in the Matapédia Group near Woodstock, 100 km to the south, may be due to large-scale gravity-induced slumping of deep-basin sediments during late-stage Taconian orogenic pulses. Subsequent northwest-southeast compression during the main Acadian deformational phase led to the development of close vertical folds on the limbs of the precleavage folds, with the regional northeast-trending slaty cleavage clearly axial planar to the vertical folds. The latter are mesoscopic in scale, with wavelengths ranging from 0.5 to 7.0 m. Typically, northeast-trending macroscopic folds in the Aroostook-Matapédia Zone are upright and tight with wavelengths (where estimation is possible) of 1.5 to 2.0 km.

Fold patterns in the study area are illustrated on stereographic plots of poles to bedding (Figure 23) and cleavage (Figure 24). Bedding plane poles for the Grog Brook and Matapédia groups (Figure 23A) lie on a crude girdle, and point maxima are consistent with isoclinal folds trending roughly 040°. Point maxima in Figure 24A illustrate that cleavage is steep and axial planar to these folds with an average trend of 038°. Figure 23A is inhomogeneous with respect to axial directions. Small clusters of poles correspond to northeast-trending, shallowly dipping beds and to northwest-trending, steeply dipping beds. The latter are a clear manifestation of local, northwest-trending precleavage folds.

In the Tobique Zone, a dome-like anticlinal structure controls the distribution of Silurian and Devonian rock units in the southwestern portion of the survey area. The core of this structure is occupied by the Lower Silurian Hazeldean Formation of the Perham Group, which is characterized by large open folds and by asymmetric, doubly plunging minor folds with wavelengths of less than 10 m to several tens of metres. The effect of these minor folds is illustrated on a plot of poles to bedding (Figure 23B), which shows a wide scatter of points reflecting a variety of bedding plane trends. Clearly, an average trend defining the anticlinal structure cannot be interpreted from this pattern. A plot of poles to cleavage in the Lower Silurian Hazeldean Formation (Figure 24B) is almost identical to that of cleavage in the Grog Brook and Matapédia groups (Figure 24A), except for a predominance in the former of steep easterly rather than steep westerly dips.

Contrasting structural styles are evident between the Hazeldean Formation and the disconformably overlying Cameron

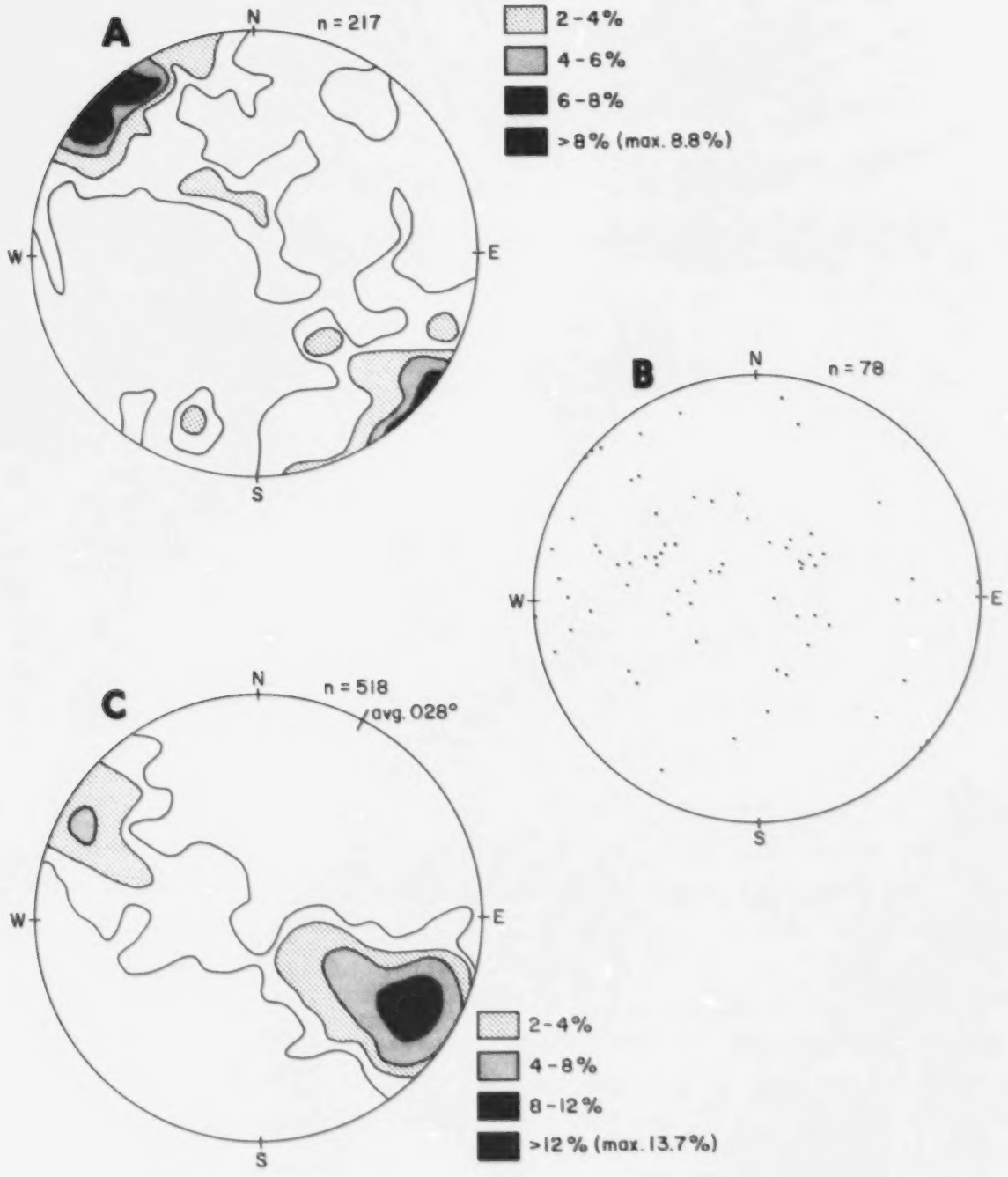

Figure 23. Poles to bedding for: A Grog Brook and Matapédia groups, B Hazeldean Formation, and C Wapske Formation.

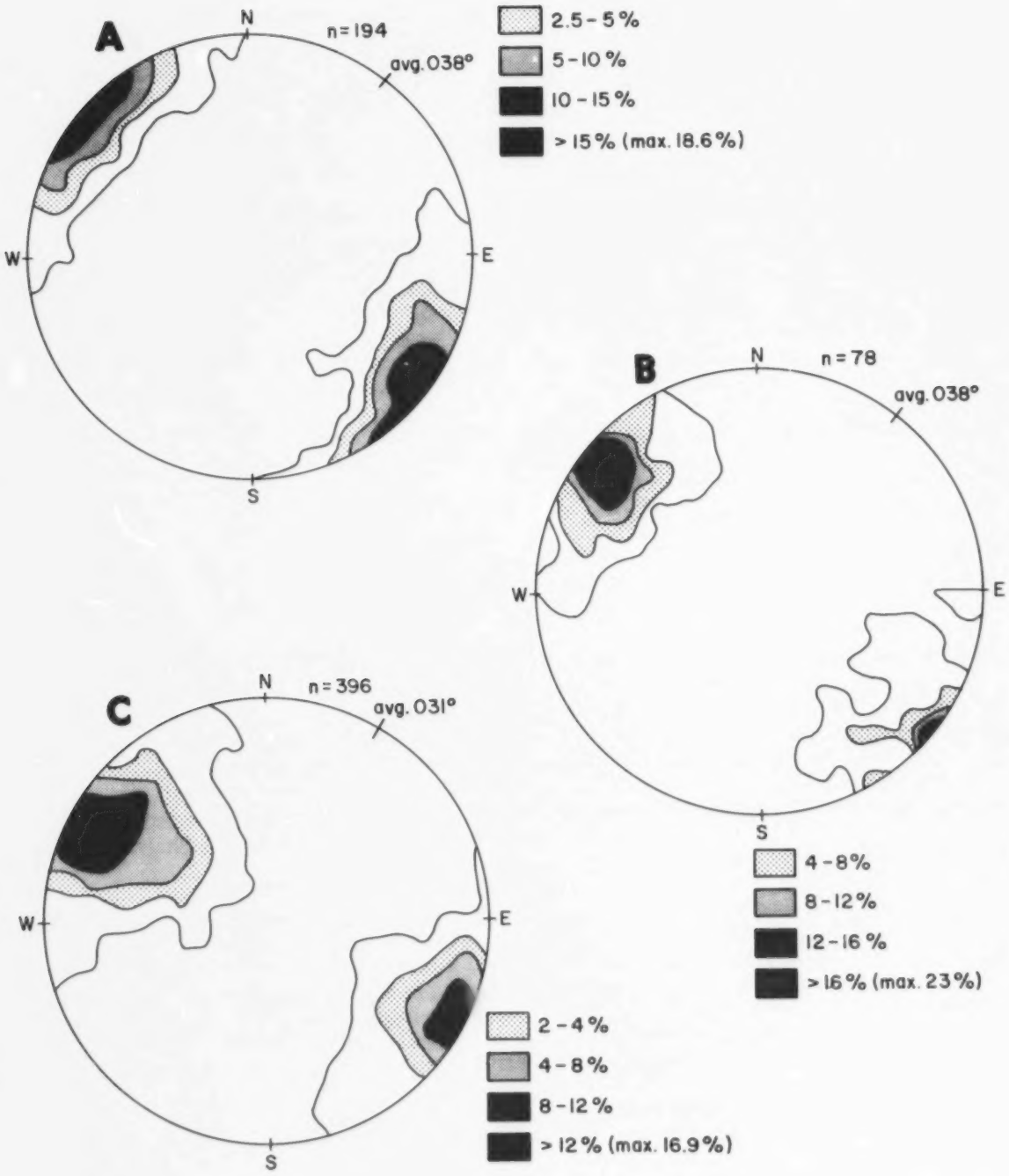

Figure 24. Poles to cleavage for: A Grog Brook and Matapédia groups, B Hazeldean Formation, and C Wapske Formation.

Mountain Formation. Although both have been affected only by Acadian tectonism, the Cameron Mountain Formation has never been observed to be infolded with the underlying Lower Silurian rocks in which minor folding is extensively developed. This may be attributed to the more ductile deformation of the Hazeldean Formation, as opposed to brittle deformation reflecting the greater competence of the conglomerates and volcanic rocks of the Cameron Mountain Formation.

The Lower Devonian sedimentary rocks of the Wapske Formation are characterized by close to tight macrofolds with local minor folds and parasitic S- or Z-shaped folds with wavelengths of about 250 m and 1 to 2 m, respectively. No major fold hinges were observed within the main belt of sedimentary rocks, where the strata dip primarily to the west, except where locally affected by minor folding. Two apparent fold axes located near the Rocky Brook-Millstream Fault suggest a half wavelength of just over 1 km. Most of the strata within the Salmon River and North View fault blocks, on the other hand, dip to the east. Fault truncation of fold hinges has obscured the original relationships between the strata within these blocks and the main sedimentary belt.

A stereographic plot of 518 poles to bedding in the Wapske Formation (Figure 23C) defines a girdle with two point maxima. The pole to this girdle indicates an average fold axial trend of 028°, with a northerly plunge of 7°. The asymmetric pattern in Figure 23C could be due to the presence of folds strongly overturned to the east. However, asymmetry would require that the axial planar cleavage should dip to the west, which is clearly not the case (Figure 24C). Therefore, the main belt of the Wapske Formation in the survey area appears to lie on the eastern limb of a large synclinal structure. The average trend of cleavage in the Wapske Formation (Figure 24C), based on 396 poles, is 031° (i.e., very close to the average fold axial trend), with steep easterly dips.

Tight folding in Wapske Formation sedimentary rocks has occurred in narrow "wedges" situated between the Cameron Mountain Formation and the Blue Bell and Rocky Brook-Millstream faults to the east and west, respectively, of the large anticlinal structure southeast of New Denmark. It appears that the volcanic rocks served as a buttress, enhancing ductile strain in the adjacent sediments during northwest-southeast Acadian compression. This feature is absent around the "nose" of the anticlinal structure, where the volcanic rocks plunge underneath the sedimentary rocks and do not create the buttress effect.

FAULTS

The survey area is transected by several prominent east-northeast- to north-northeast-trending faults. Exposure is generally very poor in their vicinity; hence, identification and location has been based largely on abrupt lithologic discontinuities, topographic expression, and aeromagnetic signatures. Quartz or calcite flooding, bedding/cleavage rotation, and cataclastic fabrics are rarely observed due to the paucity of outcrop proximal to fault traces. The intrusion of mafic plugs and dykes is common along the Rocky Brook-Millstream Fault and within the North View fault block.

The major faults in the survey area are the MacKenzie Gulch, Rocky Brook-Millstream, and Blue Bell faults. The MacKenzie Gulch Fault (St. Peter 1978a) extends for about 170 km from the Mars Hill area of eastern Maine to the Upsalquitch River in northern New Brunswick. It juxtaposes the Matapédia Group against the Grog Brook Group in the Upsalquitch River area (St. Peter 1978) and in the Sisson Branch Reservoir area (Irrinki and Crouse 1986), and is interpreted to mark the same boundary in the northwest portion of the survey area.

The Rocky Brook-Millstream Fault (Skinner 1953) extends for about 240 km in a broad arc across northern and northwestern New Brunswick. It transects the centre of the survey area in a north-northeasterly direction and juxtaposes older rocks of the Aroostook-Matapédia Zone to the west against younger rocks of the Tobique Zone to the east. Significant dextral transcurrent movement has been proposed (Skinner 1974) on the east-west-trending segment of this fault in northern New Brunswick where it forms a major tectonostratigraphic boundary. In the survey area, however, the ages of rocks on either side can be used only to indicate that the east side has been down-faulted relative to the west side.

The Blue Bell Fault (new name) had not been recognized previously in the survey area, although its northeastern extension was mapped by Irrinki and Crouse (1986) along the Mamozekel River. It begins as a splay of the Rocky Brook-Millstream Fault near the southwestern corner of the map area, trends east-northeast as far as Crombie Settlement, then strikes northeast as far as the map boundary. The northeastern limit of this fault is unknown.

The Blue Bell Fault forms a major lithological break in the southern portion of the survey area, north and east of Blue Bell Mountain, where it juxtaposes Lower Silurian and Lower Devonian strata against Carboniferous redbeds of the Plaster Rock Basin. It is evident from the distribution of Cameron Mountain Formation strata on each side of the fault and the absence of the Hazeldean

Formation south of the fault that the south side has been down-thrown relative to the north side. The topographic expression of the Blue Bell Fault is typically very pronounced, as it forms scarps between Bell Grove and Three Brooks Deadwater and along the western margin of Haley Plain where it marks the boundary of the Plaster Rock Carboniferous Basin.

Anastomosing minor faults are located between the MacKenzie Gulch and Rocky Brook-Millstream faults. The Salmon River and Foley Brook faults form the northwest and southeast boundaries of the Salmon River fault block. The Salmon River Fault, which apparently represents a splay of the Rocky Brook-Millstream Fault, can be traced from the mouth of Salmon River (Fyffe 1982d) to Chambord Brook in the survey area. The presence of younger strata on the east side of the fault, i.e., Wapske Formation sedimentary rocks in the Salmon River fault block, indicates that the east side has been down-faulted relative to the west side. The North View and Sisson Ridge faults mark the western and eastern limits of the North View fault block. They appear to be extensions of reverse faults mapped farther south by St. Peter (1979), and coalesce with the Blue Bell Fault within the survey area. Average bedding and cleavage trends within the Salmon River and North View fault blocks suggest that they have undergone minor clockwise and counter-clockwise rotation, respectively.

The Haley Brook Fault has been interpreted on the basis of topographic linears recognized in the northeastern portion of the survey area where it is subparallel to the Blue Bell Fault. The Haley Brook Fault coalesces with the Blue Bell Fault near Burntland Brook, and appears to represent a splay of that fault.

The MacKenzie Gulch, Rocky Brook-Millstream, and Blue Bell faults all disrupt Acadian fold structures and thus postdate the main phase of Acadian deformation. No cataclastic deformation has been noted in (Middle to Upper Devonian?) gabbroic intrusive rocks adjacent to the Rocky Brook-Millstream Fault, implying that no movement occurred on the fault during or after emplacement of the intrusions. However, exposure of the mafic intrusions is very limited, especially in proximity to the fault. The North View and Sisson Ridge faults offset Mississippian beds to the south (St. Peter 1979) and therefore are Mississippian or younger.

METAMORPHISM

Ordovician to Devonian sedimentary and volcanic rocks in the survey area contain prehnite-pumpellyite facies (Coombs 1960)

metamorphic mineral assemblages. In mafic volcanic rocks, plagioclase has been altered to albite, calcite, chlorite, prehnite, white mica, or epidote, and augite has been altered to chlorite, epidote, and/or sphene. Therefore, the metamorphic mineral assemblage in mafic volcanic rocks is albite + chlorite + calcite ± epidote ± sphene ± prehnite ± white mica. Actinolite was not identified in thin section examinations except in mafic intrusive rocks, where it is probably of deuteric origin. Analcime was also tentatively identified in a few sections by its isotropic character. Felsic volcanic rocks and sedimentary rocks typically contain the assemblage chlorite + calcite + white mica ± sphene.

Metamorphism in the survey area is similar to that developed in Aroostook County, Maine. Richter and Roy (1976) recognized prehnite-pumpellyite facies metamorphism in northern Maine as Seki's (1969) intermediate-pressure type, based on mixed prehnite-pumpellyite and actinolite-epidote assemblages. Rocks in the survey area lack actinolite and pumpellyite, and hence appear to conform to Seki's (1969) low-pressure-type metamorphism.

ECONOMIC GEOLOGY

No mineral deposits or significant occurrences are presently known within the survey area. In 1974, Amoco Canada Petroleum (Maingot 1974) investigated lead-zinc silt anomalies in three tributaries of Little Salmon River and staked 79 claims within felsic volcanic rocks northwest of Cameron Mountain. Amoco outlined several copper, lead, and zinc soil anomalies with maximum values of 44, 470, and 375 ppm, respectively, but subsequently dropped the claims. In 1978-79, Lacana Mining Corp. discovered three copper-uranium showings in Carboniferous redbeds of the Plaster Rock Basin in the North View area (MacNabb 1978; MacNabb and Pichette 1979). Copper and uranium were associated with carbonaceous material (up to 98 ppm U and 4350 ppm Cu) and in concretions (2.43% U and 8.32% Cu in one nodule) within restricted zones.

No mineralization other than pyrite in some volcanic rocks was observed in the survey area, and rock alteration is rare. Nevertheless, lithogeochemical analysis was carried out on 28 samples to assist in mineral potential evaluation. Included are 15 samples (ND-1-9, 11-13, 16, 20, 21) of felsic volcanic rocks, 5 samples (ND-18, 25-28) of mafic intrusive rocks, 4 samples (ND-15, 17, 19, 22) of altered sedimentary rocks, 2 samples (ND-23, 24) of altered basalts, 1 sample (ND-14) of hematitic mafic breccia or coarse tuff, and 1 sample (ND-10) of polymictic conglomerate. The results of these analyses are presented in

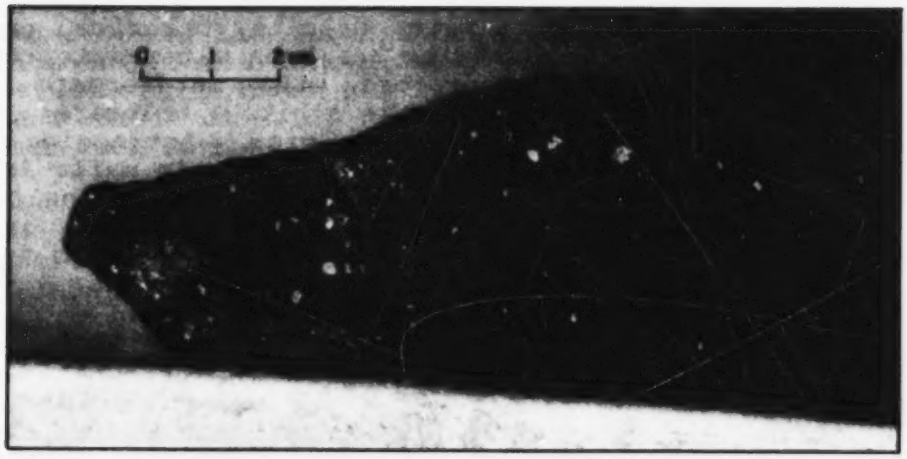

Figure 25. Strongly altered and hematitized mafic volcanic rocks interbedded with Blue Mountain Rhyolite, collected on the Tobique River near Blue Mountain Bend.

Table 4, and the sample locations are shown on Plate 89-72(R). The most interesting results are from two samples of altered sedimentary rocks in the North View area: ND-15 is a bleached siltstone containing 100 ppm Sb and greater than 1000 ppb Hg, whereas ND-17 is a limonite-stained siltstone containing 11 ppb Au and 160 ppb Hg. Samples ND-20 and ND-21 from the Blue Mountain Rhyolite are strongly depleted in sodium and enriched in potassium, suggesting that alteration has occurred, although the rocks look relatively fresh; ND-20 also contains 235 ppm As. Samples ND-23 and 24 are altered, hematite-veined basalts (Figure 25) interbedded with felsic volcanic and sedimentary rocks of the Blue Mountain Rhyolite. They are also depleted in sodium and enriched in potassium, although less extensively. Sample ND-23 contains anomalous antimony (32 ppm).

The Blue Mountain Rhyolite may be the source of a 3090 ppb gold-in-silt geochemical anomaly located at the mouth of Watson Brook. This anomaly was revealed during a release of geochemical data by the Minerals and Energy Division of the New Brunswick Department of Natural Resources and Energy in 1987. If not spurious (i.e., laboratory or sampling error), it must be due to the presence of a grain of gold in the sample derived either from the rhyolites of the Blue Mountain belt, or a paleoplacer source in the Carboniferous redbeds along the Tobique River.

A recent till geochemical survey (Pronk and Parkhill 1989) in the Riley Brook map area (NTS 21 O/3) has outlined a number

TABLE 4
LITHOGEOCHEMICAL ANALYSES

	Au	As	Sb	Hg	Ba	Cu	Pb	Zn	Th	U	Na	K
ND- 1	<1	5	<3	25	336	<1	12	56	16	7	27000	40000
ND- 2	<1	<3	<3	30	172	<1	8	49	15	<2	22000	49000
ND- 3	<1	12	<3	12	308	<1	21	63	14	4	33000	29000
ND- 4	1	4	7	35	168	<1	13	201	3	<2	4500	20000
ND- 5	<1	34	9	93	154	<1	56	71	11	<2	14000	14000
ND- 6	<1	4	4	52	79	<1	14	60	2	5	1100	12000
ND- 7	<1	<3	8	30	62	<1	10	32	15	3	500	7500
ND- 8	<1	<3	<3	41	192	<1	10	67	15	<2	12000	45000
ND- 9	<1	46	5	210	331	<1	23	20	17	6	31000	34000
ND-10	<1	5	<3	36	307	<1	17	73	6	<2	17000	20000
ND-11	<1	15	<3	58	103	<1	21	36	14	<2	8900	47000
ND-12	<1	2	0.7	16	241	4	10	28	21	5.5	26000	36000
ND-13	2	5	<3	130	162	<1	8	34	6	5	14000	23000
ND-14	<1	23	6	<5	197	<1	5	57	<2	<2	22000	8100
ND-15	<1	19	100	>1000	162	11	84	29	8.6	1.9	700	7700
ND-16	<1	39	5	8	183	<1	168	34	20	8	54000	22000
ND-17	11	11	4.2	160	132	17	44	17	7.1	1.7	600	6600
ND-18	<1	2	<0.2	5	1140	41	<2	74	1.2	0.4	31000	3300
ND-19	2	36	<3	65	225	<1	20	63	2	<2	13000	11000
ND-20	<1	235	3	36	796	<1	35	19	<2	5	1500	68000
ND-21	<1	25	9	69	866	<1	22	27	13	<2	1800	74000
ND-22	<1	20	14	69	169	4	13	57	5	<2	13000	15000
ND-23	<1	33	32	7	NA	7	10	41	11.1	1.5	900	27000
ND-24	<1	<1	3.6	10	223	6.5	44	29	9.2	2.3	800	14000
ND-25	<1	23	3.1	26	NA	31	8	79	NA	NA	26000	18000
ND-26	<1	4	6.3	13	NA	35	<2	70	NA	NA	35000	11000
ND-27	<1	1	0.2	16	NA	36	<2	69	NA	NA	29000	4800
ND-28	<1	1	0.3	26	NA	84	<2	91	NA	NA	23000	5500

Note: All values are ppm except Au and Hg, which are ppb. Sample locations are plotted on Plate 89-72(R).

NA - Not Analysed

of anomalies. Several gold, mercury, arsenic, and/or antimony anomalies show a close spatial association with the Rocky Brook-Millstream Fault and the mafic intrusions that have been emplaced along it. In the Upsalquitch Forks area to the northeast, altered mafic dykes spatially related to the Rocky Brook-Millstream Fault system are known to be auriferous. Although the gabbros observed along the Rocky Brook-Millstream Fault in the survey area are not altered or geochemically anomalous, it should be reiterated that exposure is very poor and few samples could be collected. Scattered, low-level gold, mercury, arsenic, and/or antimony anomalies are located between the Blue Bell Fault and the Tobique River, possibly dispersed eastward from a source near the Blue Bell or Sisson Ridge Fault. A number of gold-in-till anomalies, ranging from 10 to 29 ppb Au, with a maximum of 73 ppb Au, form a north-south-trending belt in the centre of the survey area extending from the mafic intrusions near the Rocky Brook-Millstream Fault, almost as far south as the Mafic Volcanic Member of the Cameron Mountain Formation. This area is characterized by some of the poorest exposures in the survey area. However, it is assumed to be underlain by sedimentary rocks typical of the Wapske Formation. The source of these anomalies remains unknown.

A silt geochemical survey of north-central New Brunswick was carried out during the summer of 1988 by K.D.A. Whaley on behalf of the Geological Survey of Canada (Friske and Hornbrook 1989).

In summary, those environments most favourable for metallic mineral occurrences or deposits include: (1) the North View area as far north as Burntland Brook, particularly in proximity to the Blue Bell and Sisson Ridge faults (possible epithermal mineralization); (2) the Blue Mountain Rhyolite (exhibits local development of epithermal-style alteration); (3) within and near mafic intrusions proximal to the Rocky Brook-Millstream Fault (possible gold mineralization, unknown potential for platinum-group metals).

Industrial minerals within the survey area include limestone and granular aggregates. The highest quality limestone is that found along the Salmon River at Chambord Brook (Unit Sc). Although chemical analysis of one sample indicates that the quality is poor, other samples from this unit may prove to be higher in calcium. Analytical results are as follow:

CaO	33.92%	Na_2O	0.0031%
SiO_2	24.49%	K_2O	0.097%
MgO	1.28%	SO_3	0.28%
Al_2O_3	5.12%	L.O.I.	28.15%
Fe_2O_3	2.18%	acid insolubles	32.97%

Granular aggregate resources of the survey area have been described by Thibault (1980) and Lavergne and Hunter (1982).

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DEPARTMENT OF NATURAL RESOURCES AND ENERGY
MINERALS AND ENERGY DIVISION

NOUVEAU-BRUNSWICK
MINISTÈRE DES RESSOURCES NATURELLES ET DE L'ÉNERGIE
DIVISION DES MINÉRAUX ET DE L'ÉNERGIE

Parts of 21J/13, 21J/14, 21O/3, 21O/4

PLATE 89-72(R)

67°37'30" 47°15'00"

67°15'00" 47°15'00"

Og

OSr

OSn

FAULT

GULCH

MacKENZIE

MILLSTREAM

FAULT

BROOK

FAULT

HALEY

PLAIN

Ma

Dw

Dm

ND-28

ND-18

ND-27

ND-22

ND-19

ND-24

ND-23

ND-20

103062

103064

DENMARK PARISH
DRUMMOND PARISH

Blue Mountain Bend

NEW D

MISSI

Mp

Ma

DEVON

Dm

LOWER

Dw

Db

Dcfz

Dcm

Dcf

Dc

SILUR

Sc

Sh

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DIVISION DES MINÉRAUX ET DE L'ÉNERGIE

PLATE 89-72(R)

BEDROCK GEOLOGY OF NEW DENMARK - SALMON RIVER AREA NEW BRUNSWICK

67°15'00"
47°15'00"

OSr
OSn
OSp
Dm
Dw
Ma
Db
Dcf2
Dcm
Dcf1
Dcc
Mp
Sc
Sh
ND-28
ND-18
ND-27
ND-26
ND-22
ND-19
ND-24
ND-23
ND-20
103062
103064
MILLSTREAM FAULT
HALEY BROOK FAULT
HALEY PLAIN
Hand Brook
Right Branch
Cedar Brook
Fisher Gulch
Salmon River
East Branch
Blue Mountain Road

LEGEND

MISSISSIPPIAN

Plaster Rock Formation

Mp Red and green shale; limestone; gypsum

Arthurette Redbeds

Ma Red sandstone, conglomerate, mudstone

DEVONIAN

Dm Gabbro

LOWER DEVONIAN

TOBIQUE GROUP
Wapske Formation

Dw Grey to green quartzose or argillaceous siltstone and fine- to medium-grained, calcareous to noncalcareous, micaceous, quartzose to arkosic sandstone; minor grey to green shale and slate

Blue Mountain Rhyolite

Db Red, red-brown, or maroon, typically flow-banded, locally porphyritic rhyolite; minor maroon rhyolite tuff, grey to green rhyolite, pillow basalt, and brown to maroon siltstone

Cameron Mountain Formation

Dcf2 Upper Felsic Member: pink to red massive aphanitic rhyolite; minor flow-banded rhyolite, pillow basalt, volcaniclastic and quartzose sedimentary rocks

Dcm Mafic Volcanic Member: dark grey, dark green, or olive-green massive to pillowed basalt; amygdaloidal or vesicular basalt; hyaloclastite; mafic tuff; minor calcareous quartzose siltstone and felsic volcanic rocks

Dcf1 Lower Felsic Member: pink to buff, massive to flow-banded, locally porphyritic rhyolite; felsic pyroclastic rocks; local volcaniclastic and mafic volcanic rocks

Dcc Polymictic Conglomerate Member: polymictic conglomerate, red to purple or maroon sandstone and siltstone

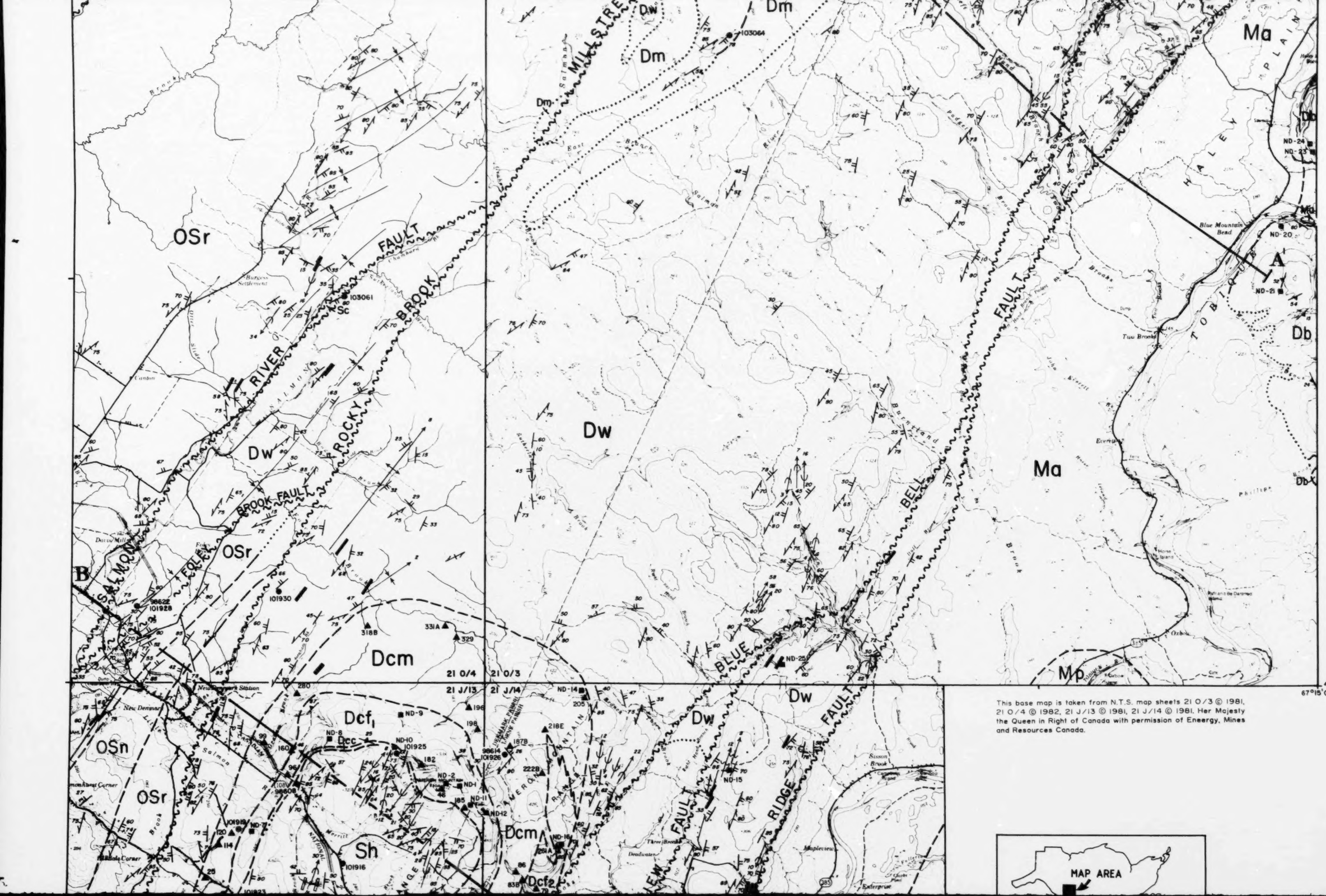
SILURIAN

PERHAM GROUP
Chambord Brook Limestone

Sc Grey to pink limestone, red-brown silty limestone

Hazeldean Formation

Sh Grey to green, massive to parallel-laminated calcareous siltstone and fine-grained sandstone; massive, fine- to medium-grained quartzoae sandstone; minor silty shale,



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Dcm — olive-green massive to pillowed basalt; amygdaloidal or vesicular basalt; hyaloclastite; mafic tuff; minor calcareous quartzose siltstone and felsic volcanic rocks

Dcf1 — Lower Felsic Member: pink to buff, massive to flow-banded, locally porphyritic rhyolite; felsic pyroclastic rocks; local volcaniclastic and mafic volcanic rocks

Dcc — Polymictic Conglomerate Member: polymictic conglomerate, red to purple or maroon sandstone and siltstone

SILURIAN

PERHAM GROUP
Chambord Brook Limestone

Sc — Grey to pink limestone, red-brown silty limestone

Hazeldean Formation

Sh — Grey to green, massive to parallel-laminated calcareous siltstone and fine-grained sandstone; massive, fine- to medium-grained quartzose sandstone; minor silty shale, lithic grit and sandstone, and polymictic conglomerate

UPPER ORDOVICIAN-LOWER SILURIAN

MATAPEDIA GROUP
New Denmark Argillite

OSn — Dark grey to black, massive- to parallel-laminated argillite; dark grey to light grey-green greywacke, lithic wacke, grit, and conglomerate

Ribbon Rock Unit

OSr — Dark grey to black calcareous argillite or shale, and light grey to black argillaceous limestone; minor noncalcareous shale

UPPER ORDOVICIAN

GROG BROOK GROUP

Og — Dark grey to black calcareous to noncalcareous argillite; grey-green sandstone; minor grey silty limestone

SYMBOLS

- Bedding (tops known, tops unknown, vertical, overturned)
- Cleavage (inclined, vertical)
- Primary flow layering in volcanic rocks (inclined, vertical)
- Geological contact (defined, approximate, assumed)
- Fault
- Syncline (arrow indicates plunge)
- Anticline (arrow indicates plunge)
- Minor fold (synform, antiform; arrow indicates plunge)
- Pre-cleavage fold (synform, antiform; arrow indicates plunge)
- Multiple fold (arrow indicates plunge)
- Dyke (mafic, felsic)
- Lithogeochemical sample location

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MAP AREA

47°00'00"
67°15'00"

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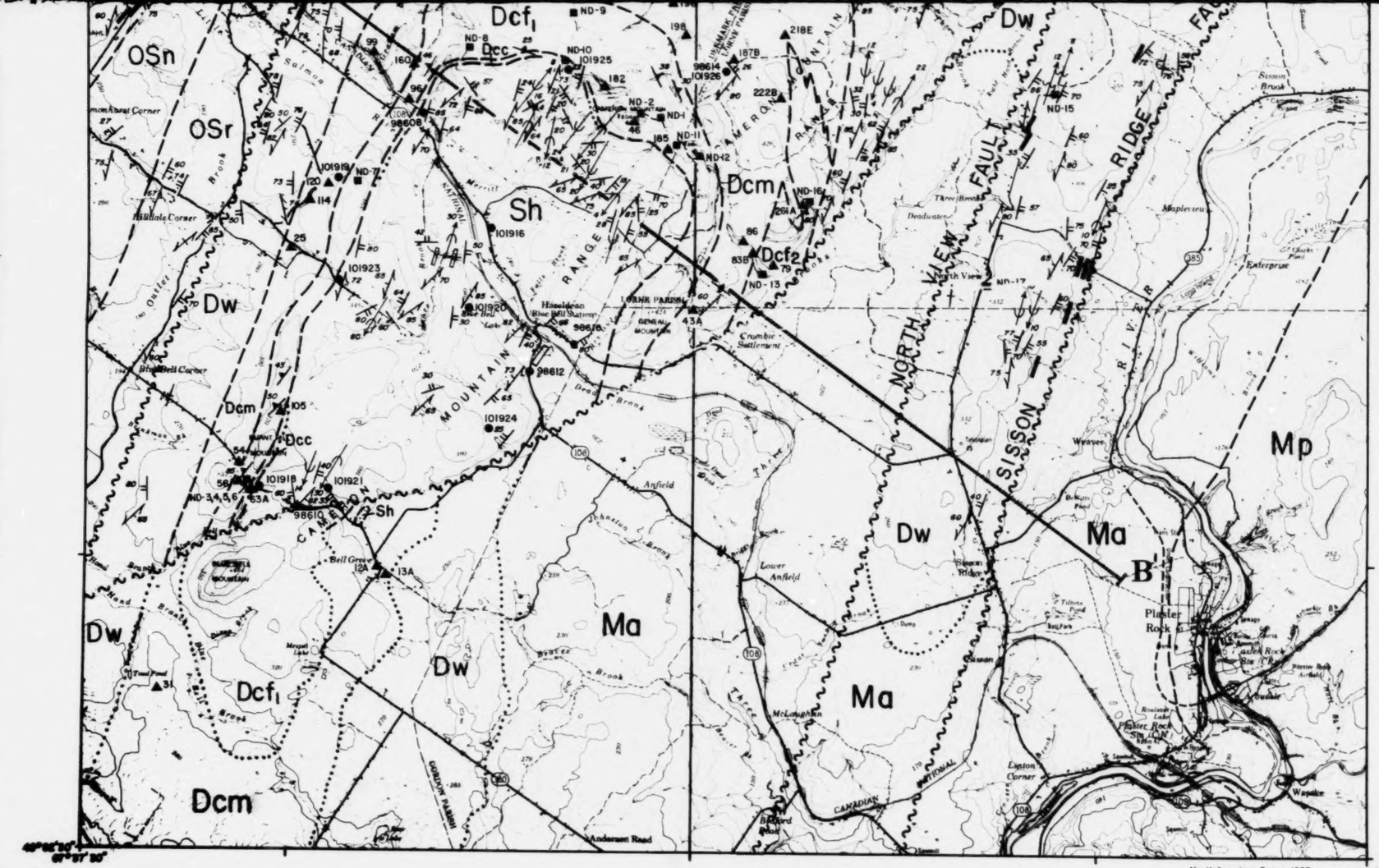
Geology
Drafted

This map

WILSON,
area, N
Resource

Canada-New Brunswick Mineral Development Agreement
Entente Canada-Nouveau-Brunswick L'Exploration Minérale

This project was funded under the Canada-New Brunswick Mineral Development Agreement, a subsidiary agreement under the Economic and Regional Development Agreement.
Ce projet fut financé en vertu de l'entente Canada-Nouveau-Brunswick sur l'exploitation minérale, une entente auxiliaire de l'entente cadre sur le développement économique et régional.

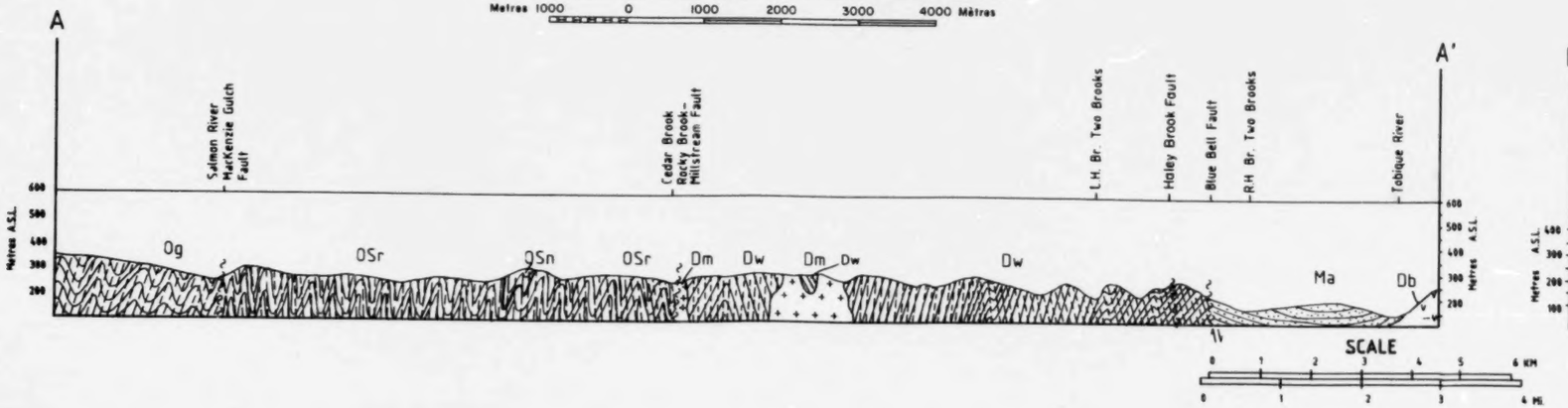


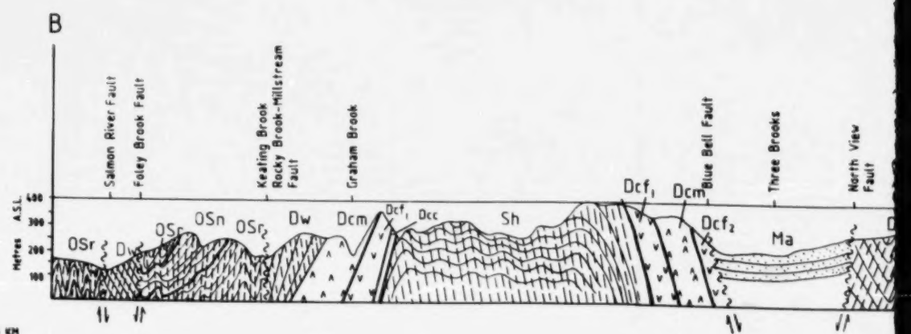
46°52'30"
67°27'30"

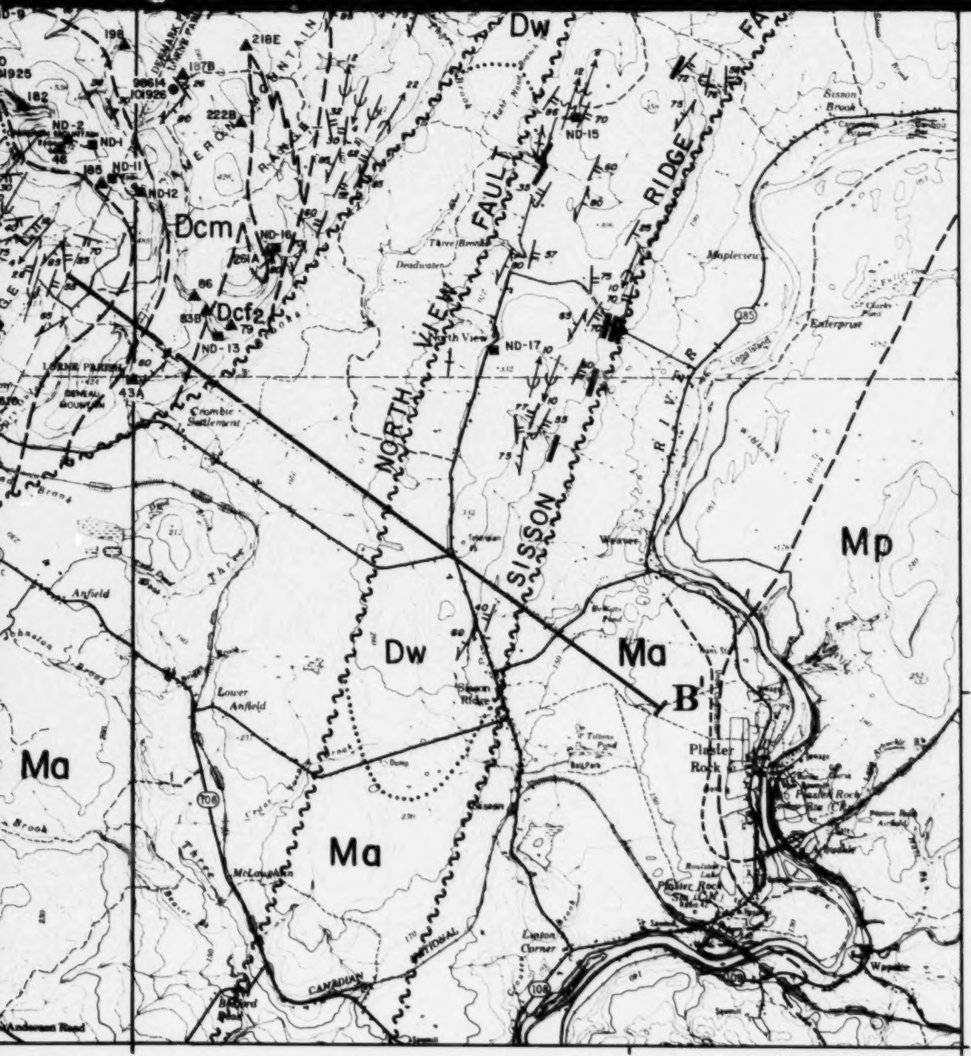
North American Datum 1927
Système de référence géodésique nord-américain, 1927

67°21'30"

Miles 1 0 1 2 3 Miles
Metres 1000 0 1000 2000 3000 4000 Mètres







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Syncline (arrow indicates plunge)

Anticline (arrow indicates plunge)

Minor fold (synform, antiform; arrow indicates plunge)

Pre-cleavage fold (synform, antiform; arrow indicates plunge)

Multiple fold (arrow indicates plunge)

Dyke (mafic, felsic)

Lithogeochemical sample location

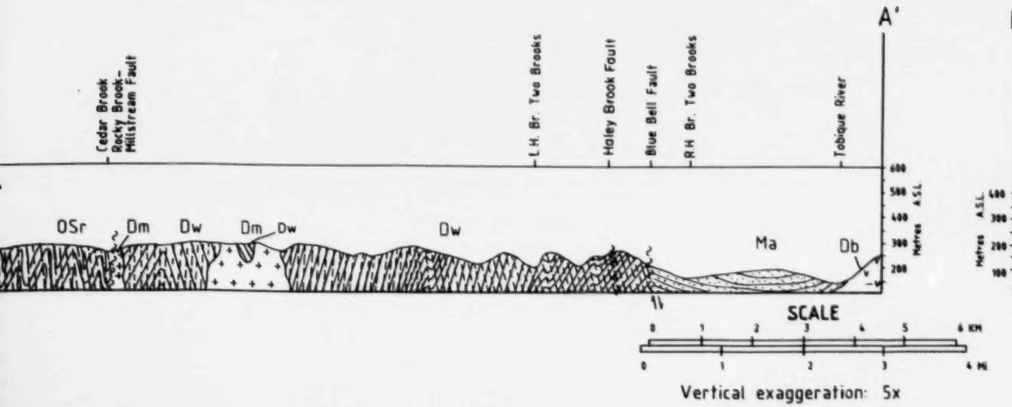
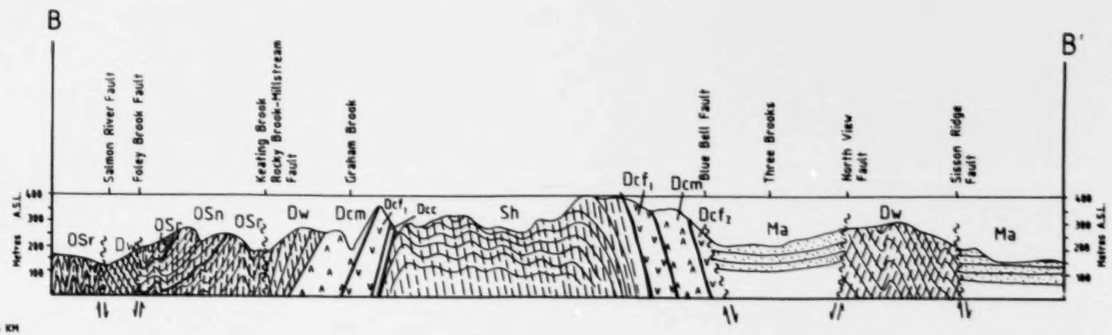
Location of sample for whole-rock analysis

Location of fossil collection with GSC identification number

Geology by R.A. Wilson (1986-87)
Drafted by T.L. Leonard (1989)

This map should be referenced in the following manner:

WILSON, R.A. 1989. Bedrock geology, New Denmark - Salmon River area, New Brunswick. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Plate 89-72(R).

To accompany Report of Investigation 23.

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